THE POSTHUMOUS AND *Other Writings* OF BENJAMIN FRANKLIN,

LL.D. F.R.S., &c.

MINISTER PLENIPOTENTIARY FROM THE UNITED STATES OF AMERICA AT THE COURT OF FRANCE, AND FOR THE TREATY OF PEACE AND INDEPENDENCE WITH GREAT BRITAIN, &c. &c.

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MEMOIRS

OF

BENJAMIN FRANKLIN.

PART III.

GENERAL POLITICS AND COMMERCE.

OBSERVATIONS CONCERNING THE INCREASE OF MANKIND, PEOPLING OF COUNTRIES, &c.

Written in Pennsylvania, 1751.

1. TABLES of the proportion of marriages to births, of deaths to births, of marriages to the number of inhabitants, &c. formed on observations made upon the bills of mortality, christenings, &c. of populous cities, will not suit countries; nor will tables formed and observations made on full settled old countries, as Europe, suit new countries, as America.

2. For people increase in proportion to the number of marriages, and that is greater in proportion to the ease and convenience of supporting a family. When families can be easily supported, more persons marry, and earlier in life.

3. In cities, where all trades, occupations, and offices are full, many delay marrying till they can see how to bear the charges of a family; which charges are greater in cities, as luxury is more common; many live single during life, and continue servants to families, journeymen to trades, &c. Hence cities do not, by natural generation, supply themselves with inhabitants; the deaths are more than the births.

4. In countries full settled, the case must be nearly the same, all lands being occupied and improved to the height; those who cannot get land, must labor for others, that have it; when laborers are plenty, their wages will be low; by low wages a family is supported with difficulty; this difficulty deters many from marriage, who therefore long continue servants and single. Only, as the cities take supplies of people from the country, and thereby make a little more room in the country, marriage is a little more encouraged there, and the births exceed the deaths.

5. Great part of Europe is fully settled with husbandmen, manufacturers, &c. and therefore cannot now much increase in people. America is chiefly occupied by Indians, who subsist mostly by hunting. But as the hunter, of all men, requires the greatest quantity of land from whence to draw his subsistence, (the husbandman subsisting on much less, the gardener on still less, and the manufacturer requiring least of all) the Europeans found

America as fully settled, as it well could be by hunters; yet these, having large tracts, were easily prevailed on to part with portions of territory to the new comers, who did not much interfere with the natives in hunting, and furnished them with many things they wanted.

6. Land being thus plenty in America, and so cheap, as that a laboring man, that understands husbandry, can, in a short time, save money enough to purchase a piece of new land, sufficient for a plantation, whereon he may subsist a family; such are not afraid to marry: for if they even look far enough forward to consider how their children, when grown up, are to be provided for, they see, that more land is to be had at rates equally easy, all circumstances considered.

7. Hence marriages in America are more general, and more generally early, than in Europe. And if it is reckoned there, that there is but one marriage *per annum* among 100 persons, perhaps we may here reckon two; and if in Europe, they have but four births to a marriage, (many of their marriages being late) we may here reckon eight, of which, if one half grow up, and our marriages are made, reckoning one with another, at twenty years of age, our people must at least be doubled every twenty years.

8. But notwithstanding this increase, so vast is the territory of North America, that it will require many ages to settle it fully; and till it is fully set-

tled, labor will never be cheap here, where no man continues long a laborer for others, but gets a plantation of his own; no man continues long a journeyman to a trade, but goes among those new settlers, and sets up for himself, &c. Hence labor is no cheaper now, in Pennsylvania, than it was thirty years ago, though so many thousand laboring people have been imported from Germany and Ireland.

9. The danger, therefore, of these colonies interfering with their mother country in trades, that depend on labor, manufactures, &c. is too remote to require the attention of Great Britain.

10. But, in proportion to the increase of the colonies, a vast demand is growing for British manufactures; a glorious market, wholly in the power of Britain, in which foreigners cannot interfere, which will increase, in a short time, even beyond her power of supplying, though her whole trade should be to her colonies. * * * * *

12. It is an ill-grounded opinion, that, by the labor of slaves, America may possibly vie in cheapness of manufactures with Britain. The labor of slaves can never be so cheap here, as the labor of working men is in Britain. Any one may compute it. Interest of money is in the colonies from 6 to 10 per cent. Slaves, one with another, cost 30*l.* sterling per head. Reckon then the interest of the first purchase of a slave, the insurance or risk on his life, his clothing and diet, expenses in his sick-

ness and loss of time, loss by his neglect of business, (neglect is natural to the man, who is not to be benefited by his own care or diligence) expense of a driver to keep him at work, and his pilfering from time to time, almost every slave being, from the nature of slavery, a thief, and compare the whole amount with the wages of a manufacturer of iron or wool in England, you will see, that labor is much cheaper there, than it ever can be by negroes here. Why then will Americans purchase slaves? Because slaves may be kept as long as a man pleases, or has occasion for their labor, while hired men are continually leaving their master (often in the midst of his business) and setting up for themselves. § 8.

13. As the increase of people depends on the encouragement of marriages, the following things must diminish a nation, viz. 1. The being conquered; for the conquerors will engross as many offices, and exact as much tribute or profit on the labor of the conquered, as will maintain them in their new establishment; and his diminishing the subsistence of the natives discourages their marriages, and so gradually diminishes them, while the foreigners increase. 2. Loss of territory. Thus the Britons, being driven into Wales, and crowded together in a barren country, insufficient to support such great numbers, diminished, till the people bore a proportion to the produce; while the Saxons increased on their abandoned lands, till the island

became full of English. And, were the English now driven into Wales by some foreign nation, there would, in a few years, be no more Englishmen in Britain, than there are now people in Wales. 3. Loss of trade. Manufactures, exported, draw subsistence from foreign countries for numbers, who are thereby enabled to marry and raise families. If the nation be deprived of any branch of trade, and no new employment is found for the people occupied in that branch, it will soon be deprived of so many people. 4. Loss of food. Suppose a nation has a fishery, which not only employs great numbers, but makes the food and subsistence of the people cheaper: if another nation becomes master of the seas, and prevents the fishery, the people will diminish in proportion as the loss of employ and dearness of provision makes it more difficult to subsist a family. 5. Bad government and insecure property. People not only leave such a country, and, settling abroad, incorporate with other nations, lose their native language, and become foreigners; but the industry of those that remain being discouraged, the quantity of subsistence in the country is lessened, and the support of a family becomes more difficult. So heavy taxes tend to diminish a people. 6. The introduction of slaves. The negroes brought into the English sugar islands, have greatly diminished the whites there: the poor are by this means deprived of employment, while a few families acquire

vast estates, which they spend on foreign luxuries; and, educating their children in the habits of those luxuries, the same income is needed for the support of one, that might have maintained one hundred. The whites, who have slaves, not laboring, are enfeebled, and therefore not so generally prolific; the slaves being worked too hard, and ill fed, their constitutions are broken, and the deaths among them are more than the births; so that a continual supply is needed from Africa. The northern colonies, having few slaves, increase in whites. Slaves also pejorate the families that use them; the white children become proud, disgusted with labor, and, being educated in idleness, are rendered unfit to get a living by industry.

14. Hence the prince, that acquires new territory, if he finds it vacant, or removes the natives to give his own people room;—the legislator, that makes effectual laws for promoting trade, increasing employment, improving land by more or better tillage, providing more food by fisheries, securing property, &c.;—and the man that invents new trades, arts or manufactures, or new improvements in husbandry, may be properly called *fathers of their nation*, as they are the cause of the generation of multitudes, by the encouragement they afford to marriage.

15. As to privileges granted to the married, (such as the *jus trium liberorum* among the Romans) they may hasten the filling of a country, that has

been thinned by war or pestilence, or that has otherwise vacant territory, but cannot increase a people beyond the means provided for their subsistence.

16. Foreign luxuries, and needless manufactures, imported and used in a nation, do, by the same reasoning, increase the people of the nation that furnishes them, and diminish the people of the nation that uses them. Laws therefore that prevent such importations, and, on the contrary, promote the exportation of manufactures to be consumed in foreign countries, may be called (with respect to the people that make them) *generative laws*, as, by increasing subsistence, they encourage marriage. Such laws likewise strengthen a country doubly, by increasing its own people, and diminishing its neighbors.

17. Some European nations prudently refuse to consume the manufactures of East India:—they should likewise forbid them to their colonies; for the gain to the merchant is not to be compared with the loss, by this means, of people to the nation.

18. Home luxury in the great increases the nation's manufacturers employed by it, who are many, and only tends to diminish the families that indulge in it, who are few. The greater the common fashionable expense of any rank of people, the more cautious they are of marriage. Therefore

luxury should never be suffered to become common.

19. The great increase of offspring in particular families is not always owing to greater fecundity of nature, but sometimes to examples of industry in the heads, and industrious education, by which the children are enabled better to provide for themselves, and their marrying early is encouraged from the prospect of good subsistence.

20. If there be a sect, therefore, in our nation, that regard frugality and industry as religious duties, and educate their children therein, more than others commonly do, such sect must consequently increase more by natural generation than any other sect in Britain.

21. The importation of foreigners into a country that has as many inhabitants as the present employments and provisions for subsistence will bear, will be in the end no increase of people, unless the new-comers have more industry and frugality than the natives, and then they will provide more subsistence, and increase in the country; but they will gradually eat the natives out. Nor is it necessary to bring in foreigners to fill up any occasional vacancy in a country; for such vacancy (if the laws are good, § 14, 16) will soon be filled by natural generation. Who can now find the vacancy made in Sweden, France, or other warlike nations, by the plague of heroism 40 years ago; in France, by the expulsion of the protestants; in England, by

the settlement of her colonies; or in Guinea, by a hundred years' exportation of slaves, that has blackened half America? The thinness of the inhabitants in Spain is owing to national pride, and idleness, and other causes, rather than to the expulsion of the Moors, or to the making of new settlements.

22. There is, in short, no bound to the prolific nature of plants or animals, but what is made by their crowding and interfering with each other's means of subsistence. Was the face of the earth vacant of other plants, it might be gradually sowed and overspread with one kind only, as, for instance, with fennel: and were it empty of other inhabitants, it might, in a few ages, be replenished from one nation only, as, for instance, with Englishmen. Thus there are supposed to be now upwards of one million of English souls in North America (though it is thought scarce 80,000 have been brought over sea), and yet perhaps there is not one the fewer in Britain, but rather many more, on account of the employment the colonies afford to manufacturers at home. This million doubling, suppose but once in 25 years, will, in another century, be more than the people of England, and the greatest number of Englishmen will be on this side the water. What an accession of power to the British empire by sea as well as land! What increase of trade and navigation! What numbers of ships and seamen! We have been here but little

more than a hundred years, and yet the force of our privateers in the late war, united, was greater, both in men and guns, than that of the whole British navy in Queen Elizabeth's time. How important an affair then to Britain is the present treaty[1] for settling the bounds between her colonies and the French? and how careful should she be to secure room enough, since on the room depends so much the increase of her people?

23. In fine, a nation well regulated is like a polypus:[2] take away a limb, its place is soon supplied: cut it in two, and each deficient part shall speedily grow out of the part remaining. Thus, if you have room and subsistence enough, as you may, by dividing, make ten polypuses out of one, you may, of one, make ten nations, equally populous and powerful: or, rather, increase the nation tenfold in numbers and strength. * * *

Remarks on some of the foregoing Observations, showing particularly the Effect which Manners have on Population.

FROM RICHARD JACKSON,[3] ESQ. OF LONDON, TO BENJAMIN FRANKLIN, ESQ. AT PHILADELPHIA.

Dear Sir,

It is now near three years since I received your

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[1] In 1751. [2] A water insect, well known to naturalists.

[3] An English barrister of eminence and an intimate friend of Dr. Franklin.

excellent *Observations on the Increase of Mankind, &c.* in which you have with so much sagacity and accuracy shown in what manner, and by what causes, that principal means of political grandeur is best promoted; and have so well supported those just inferences you have occasionally drawn, concerning the general state of our American colonies, and the views and conduct of some of the inhabitants of Great Britain.

You have abundantly proved, that natural fecundity is hardly to be considered, because the *vis generandi*, as far as we know, is unlimited; and because experience shows, that the numbers of nations are altogether governed by collateral causes, and among these none of so much force as quantity of subsistence, whether arising from climate, soil, improvement of tillage, trade, fisheries, secure property, conquest of new countries, or other favorable circumstances.

As I perfectly concurred with you in your sentiments on these heads, I have been very desirous of building somewhat on the foundation you have there laid; and was induced, by your hints in the twenty-first section, to trouble you with some thoughts on the influence manners have always had, and are always likely to have, on the numbers of people, and their political prosperity in general.

The end of every individual is its own private good. The rules it observes, in the pursuit of this

good, are a system of propositions, almost every one founded in authority; that is, deriving their weight from the credit given to one or more persons, and not from demonstration.

And this, in the most important as well as the other affairs of life, is the case even of the wisest and philosophical part of the human species; and that it should be so is the less strange, when we consider, that it is perhaps impossible to prove, that *being*, or life itself, has any other value than what is set on it by authority.

A confirmation of this may be derived from the observation, that, in every country in the universe, happiness is sought upon a different plan; and, even in the same country, we see it placed by different ages, professions, and ranks of men, in the attainment of enjoyments utterly unlike.

These propositions, as well as others framed upon them, become habitual by degrees, and, as they govern the determination of the will, I call them *moral habits*.

There is another set of habits, that have the direction of the members of the body, that I call therefore *mechanical habits*. These compose what we commonly call the *arts*, which are more or less liberal or mechanical, as they more or less partake of assistance from the operations of the mind.

The *cumulus* of the moral habits of each individual, is the manners of that individual; the *cu-*

mulus of the manners of individuals makes up the manners of a nation.

The happiness of individuals is evidently the ultimate end of political society; and political welfare, or the strength, splendor, and opulence of the state, have been always admitted, both by political writers, and the valuable part of mankind in general, to conduce to this end, and are therefore desirable.

The causes that advance or obstruct any one of these three objects, are external or internal. The latter may be divided into physical, civil, and personal; under which last head I comprehend the moral and mechanical habits of mankind. The physical causes are principally climate, soil, and number of subjects; the civil, are government and laws; and political welfare is always in a ratio composed of the force of these particular causes; a multitude of external causes, and all these internal ones, not only control and qualify, but are constantly acting on, and thereby insensibly, as well as sensibly, altering one another, both for the better and the worse, and this not excepting the climate itself.

The powerful efficacy of manners in increasing a people is manifest from the instance you mention, the Quakers; among them industry and frugality multiply and extend the use of the necessaries of life: to manners of a like kind are owing the populousness of Holland, Switzerland, China,

Japan, and most parts of Indostan, &c., in every one of which, the force of extent of territory and fertility of soil is multiplied, or their want compensated, by industry and frugality.

Neither nature nor art have contributed much to the production of subsistence in Switzerland, yet we see frugality preserves and even increases families that live on their fortunes, and which, in England, we call the gentry; and the observation we cannot but make in the southern part of this kingdom, that those families, including all superior ones, are gradually becoming extinct, affords the clearest proof that luxury (that is, a greater expense of subsistence than in prudence a man ought to consume) is as destructive as proportionable want of it; but in Scotland, as in Switzerland, the gentry, though one with another they have not one-fourth of the income, increase in number.

And here I cannot help remarking, by the bye, how well founded your distinction is between the increase of mankind in old and new settled countries in general, and more particularly in the case of families of condition. In America, where the expenses are more confined to necessaries, and those necessaries are cheap, it is common to see above one hundred persons descended from one living old man. In England, it frequently happens, where a man has seven, eight, or more children, there has not been a descendant in the next generation, occasioned by the difficulties the num-

ber of children has brought on the family, in a luxurious dear country, and which have prevented their marrying.

That this is more owing to luxury than mere want, appears from what I have said of Scotland, and more plainly from parts of England remote from London, in most of which the necessaries of life are nearly as dear, in some dearer, than London, yet the people of all ranks marry and breed up children.

Again: among the lower ranks of life, none produce so few children as servants. This is, in some measure, to be attributed to their situation, which hinders marriage, but is also to be attributed to their luxury and corruption of manners, which are greater than among any other set of people in England, and are the consequence of a nearer view of the lives and persons of a superior rank, than any inferior rank, without a proper education, ought to have.

The quantity of subsistence in England has unquestionably become greater for many ages; and yet, if the inhabitants are more numerous, they certainly are not so in proportion to our improvement of the means of support. I am apt to think there are few parts of this kingdom that have not been at some former time more populous than at present. I have several cogent reasons for thinking so of great part of the counties I am most intimately acquainted with; but, as they were pro-

bably not all most populous at the same time, and as some of our towns are visibly and vastly grown in bulk, I dare not suppose, as judicious men have done, that England is less peopled than heretofore.

The growth of our towns is the effect of a change of manners, and improvement of arts, common to all Europe; and though it is not imagined that it has lessened the country growth of necessaries, it has evidently, by introducing a greater consumption of them, (an infallible consequence of a nation's dwelling in towns) counteracted the effects of our prodigious advances in the arts.

But however frugality may supply the place, or prodigality counteract the effects, of the natural or acquired subsistence of a country, industry is, beyond doubt, a more efficacious cause of plenty than any natural advantage of extent or fertility. I have mentioned instances of frugality and industry united with extent and fertility. In Spain and Asia Minor, we see frugality joined to extent and fertility, without industry; in Ireland we once saw the same; Scotland had then none of them but frugality. The change in these two countries is obvious to every one, and it is owing to industry not yet very widely diffused in either. The effects of industry and frugality in England, are surprising; both the rent and the value of the inheritance of land, depend on them greatly more than on nature; and this, though there is no con-

siderable difference in the prices of our markets. Land of equal goodness lets for double the rent of other land lying in the same county, and there are many years' purchase difference between different counties, where rents are equally well paid and secure.

Thus manners operate upon the number of inhabitants; but of their silent effects upon a civil constitution, history, and even our own experience, yield us abundance of proofs, though they are not uncommonly attributed to external causes: their support of a government against external force is so great, that it is a common maxim among the advocates of liberty, that no free government was ever dissolved, or overcome, before the manners of its subjects were corrupted.

The superiority of Greece over Persia was singly owing to their difference of manners; and that, though all natural advantages were on the side of the latter, to which I might add the civil ones; for though the greatest of all civil advantages, liberty, was on the side of Greece, yet that added no political strength to her, but in proportion as it operated on her manners; and, when they were corrupted, the restoration of their liberty by the Romans overturned the remains of their power.

Whether the manners of ancient Rome were at any period calculated to promote the happiness of individuals, it is not my design to examine; but that their manners, and the effects of those man-

ners on their government and public conduct, founded, enlarged, and supported, and afterwards overthrew their empire, is beyond all doubt. One of the effects of their conquest, furnishes us with a strong proof, how prevalent manners are even beyond quantity of subsistence; for, when the custom of bestowing on the citizens of Rome corn enough to support themselves and families was become established, and Egypt and Sicily produced the grain that fed the inhabitants of Italy, this became less populous every day, and the *jus trium liberorum* was but an expedient that could not balance the want of industry and frugality.

But corruption of manners did not only thin the inhabitants of the Roman empire, it rendered the remainder incapable of defence long before its fall, perhaps before the dissolution of the republic; so that without standing disciplined armies, composed of men whose moral habits principally, and mechanical habits secondarily,* made them different from the body of the people, the Roman empire had been a prey to the barbarians many ages before it was.

By the mechanical habits of the soldiery, I mean their discipline and the art of war; and that this is but a secondary quality appears from the inequality that has in all ages been between raw though well disciplined armies and veterans; and more from the irresistible force a single moral habit, religion

nas conferred on troops, frequently neither disciplined nor experienced.

The military manners of the *noblesse* in France, compose the chief force of that kingdom; and the enterprising manners and restless dispositions of the inhabitants of Canada, have enabled a handful of men to harass our populous, and, generally, less martial colonies; yet neither are of the value they seem at first, because overbalanced by the defect they occasion of other habits that would produce more eligible political good: and military manners in a people are not necessary in an age and country where such manners may be occasionally formed and preserved among men enough to defend the state; and such a country is Great Britain; where, though the lower class of people are by no means of a military cast, yet they make better soldiers than even the *noblesse* of France.

The inhabitants of this country, a few ages back, were to the populous and rich provinces of France, what Canada is now to the British colonies. It is true, there was less disproportion between their natural strength; but I mean, that the riches of France were a real weakness, opposed to the military manners founded upon poverty and a rugged disposition, compared to the character of the English; but it must be remembered, that at this time the manners of a people were not distinct from that of their soldiery; for the use of standing

armies has deprived a military people of the advantages they before had over others; and though it has been often said, that civil wars give power, because they render all men soldiers, I believe this has only been found true in internal wars following civil wars, and not in external ones; for now, in foreign wars, a small army, with ample means to support it, is of greater force than one more numerous, with less. This last fact has often happened between France and Germany.

The means of supporting armies, and consequently the power of exerting external strength, are best found in the industry and frugality of the body of a people living under a government and laws that encouraged commerce: for commerce is at this day almost the only stimulus that forces every one to contribute a share of labor for the public benefit.

But such is the human frame, and the world is so constituted, that it is a hard matter to possess one's self of a benefit, without laying one's self open to a loss on some other side; the improvements of manners of one sort often deprave those of another: thus we see industry and frugality under the influence of commerce, which I call a commercial spirit, tend to destroy, as well as support, the government it florishes under.

Commerce perfects the arts, but more the mechanical than the liberal, and this for an obvious reason; it softens and enervates the manners.

Steady virtue and unbending integrity are seldom to be found where a spirit of commerce pervades every thing; yet the perfection of commerce is, that every thing should have its price. We every day see its progress, both to our benefit and detriment here. Things, that *boni mores* forbid to be set to sale, are become its objects, and there are few things indeed *extra commercium*. The legislative power itself has been *in commercio*, and church livings are seldom given without consideration, even by sincere Christians, and, for consideration, not seldom to very unworthy persons. The rudeness of ancient military times, and the fury of more modern enthusiastic ones, are worn off; even the spirit of forensic contention is astonishingly diminished, all marks of manners softening; but luxury and corruption have taken their places, and seem the inseparable companions of commerce and the arts.

I cannot help observing, however, that this is much more the case in extensive countries, especially at their metropolis, than in other places. It is an old observation of politicians, and frequently made by historians, that small states always best preserve their manners. Whether this happens from the greater room there is for attention in the legislature, or from the less room there is for ambition and avarice, it is a strong argument, among others, against an incorporating union of the colonies in America, or even a federal one, that may

tend to the future reducing them under one government.

Their power, while disunited, is less, but their liberty, as well as manners, is more secure; and, considering the little danger of any conquest to be made upon them, I had rather they should suffer something through disunion, than see them under a general administration less equitable than that concerted at Albany.[1]

I take it, the inhabitants of Pennsylvania are both frugal and industrious beyond those of any province in America. If luxury should spread, it cannot be extirpated by laws. We are told by Plutarch, that Plato used to say, *It was a hard thing to make laws for the Cyrenians, a people abounding in plenty and opulence.*

But from what I set out with, it is evident, if I be not mistaken, that education only can stem the torrent, and, without checking either true industry or frugality, prevent the sordid frugality and laziness of the old Irish, and many of the modern Scotch, (I mean the inhabitants of that country, those who leave it for another being generally industrious,) or the industry, mixed with luxury, of this capital, from getting ground, and, by rendering ancient manners familiar, produce a

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[1] See an account of this plan in MEMOIRS OF THE LIFE, Part II. p. 105. 4to. Edit. and the plan itself, page 1 of this volume.

reconciliation between disinterestedness and commerce; a thing we often see, but almost always in men of a liberal education.

To conclude: when we would form a people, soil and climate may be found at least sufficiently good; inhabitants may be encouraged to settle, and even supported for a while; a good government and laws may be framed, and even arts may be established, or their produce imported: but many necessary moral habits are hardly ever found among those who voluntarily offer themselves in times of quiet at home, to people new colonies; besides that the moral as well as mechanical habits, adapted to a mother-country, are frequently not so to the new settled one, and to external events, many of which are always unforeseen. Hence it is we have seen such fruitless attempts to settle colonies, at an immense public and private expense, by several of the powers of Europe: and it is particularly observable, that none of the English colonies became any way considerable, till the necessary manners were born and grew up in the country, excepting those to which singular circumstances at home forced manners fit for the forming a new state. I am, Sir, &c.

R. JACKSON.

ON THE PRICE OF CORN, AND MANAGEMENT OF THE POOR.[1]

To Messieurs the Public.

I am one of that class of people that feeds you all, and at present is abused by you all;—in short, I am a *farmer*.

By your newspapers we are told, that God had sent a very short harvest to some other countries

[1] The following extracts of a letter, signed *Columella*, and addressed to the editors of *the Repository for select Papers on Agriculture, Arts, and Manufactures*, (see Vol. I. p. 352,) will again serve the purpose of preparing those who read it, for entering upon this paper.

"GENTLEMEN,

"There is now publishing in France a periodical work, called *Ephemerides du Citoyen*, in which several points interesting to those concerned in agriculture, are from time to time discussed by some able hands. In looking over one of the volumes of this work a few days ago, I found a little piece written by one of our countrymen, and which our vigilant neighbors had taken from *the London Chronicle* in 1766. The author is a gentleman well known to every man of letters in Europe; and perhaps there is none, in this age, to whom mankind in general are more indebted.

"That this piece may not be lost to our own country, I beg you will give it a place in your Repository: it was written in favor of the farmers, when they suffered so much abuse in our public papers, and were also plundered by the mob in many places."

The principles on which this piece is grounded, are given more at large in the *Political Fragments*, Art. 2. B.V.

of Europe. I thought this might be in favor of Old England; and that now we should get a good price for our grain, which would bring millions among us, and make us flow in money: that, to be sure, is scarce enough.

But the wisdom of government forbad the exportation.[1]

Well, says I, then we must be content with the market price at home.

No, say my lords the mob, you sha'n't have that. Bring your corn to market if you dare;—we'll sell it for you, for less money, or take it for nothing.

Being thus attacked by both ends *of the constitution*, the head and the tail *of government*, what am I to do?

Must I keep my corn in the barn to feed, and increase the breed of rats?—be it so;—they cannot be less thankful than those I have been used to feed.

Are we farmers the only people to be grudged the profits of our honest labor?—And why? One of the late scribblers against us, gives a bill of fare of the provisions at my daughter's wedding,

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[1] It is not necessary to repeat in what degree Dr. Franklin respected the ministers, to whom he alludes.—The embargo upon corn was but a single measure; which, it is enough to say, a host of politicians thought well advised, but ill defended. —Of the great and honorable services of the Earl of Chatham to his country, Dr. Franklin has borne the amplest testimony. B. V.

and proclaims to all the world, that we had the insolence to eat beef and pudding!—Has he not read the precept in the good book, *Thou shalt not muzzle the mouth of the ox that treadeth out the corn;* or does he think us less worthy of good living than our oxen?

O, but the manufacturers! the manufacturers! they are to be favored, and they must have bread at a cheap rate!

Hark ye, Mr. Oaf;—the farmers live splendidly, you say. And pray, would you have them hoard the money they get? Their fine clothes and furniture, do they make them themselves, or for one another, and so keep the money among them? Or, do they employ these your darling manufacturers, and so scatter it again all over the nation?

The wool would produce me a better price, if it were suffered to go to foreign markets; but that, Messieurs the Public, your laws will not permit. It must be kept all at home, that our *dear* manufacturers may have it the cheaper. And then, having yourselves thus lessened our encouragement for raising sheep, you curse us for the scarcity of mutton!

I have heard my grandfather say, that the farmers submitted to the prohibition on the exportation of wool, being made to expect and believe that when the manufacturer bought his wool cheaper, they should also have their cloth cheaper. But the deuce a bit. It has been growing dearer

and dearer from that day to this. How so? Why, truly, the cloth is exported; and that keeps up the price.

Now, if it be a good principle, that the exportation of a commodity is to be restrained, that so our people at home may have it the cheaper, stick to that principle, and go thorough stitch with it. Prohibit the exportation of your cloth, your leather, and shoes, your iron ware, and your manufactures of all sorts, to make them all cheaper at home. And cheap enough they will be, I will warrant you—till people leave off making them.

Some folks seem to think they ought never to be easy till England becomes another Lubberland, where it is fancied the streets are paved with penny rolls, the houses tiled with pancakes, and chickens, ready roasted, cry, Come eat me!

I say, when you are sure you have got a good principle, stick to it, and carry it thorough. I hear it is said, that though it was *necessary and right* for the m———y to advise a prohibition of the exportation of corn, yet it was *contrary to law;* and also, that though it was *contrary to law* for the mob to obstruct waggons, yet it was *necessary and right.* Just the same thing to a tittle. Now they tell me, an act of indemnity ought to pass in favor of the m———y, to secure them from the consequences of having acted illegally. If so, pass another in favor of the mob. Others say, some of the mob ought to be hanged, by way of

example. If so,—but I say no more than I have said before, *when you are sure that you have got a good principle, go thorough with it.*

You say, poor laborers cannot afford to buy bread at a high price, unless they had higher wages. Possibly. But how shall we farmers be able to afford our laborers higher wages, if you will not allow us to get, when we might have it, a higher price for our corn?

By all that I can learn, we should at least have had a guinea a quarter more, if the exportation had been allowed. And this money England would have got from foreigners.

But, it seems, we farmers must take so much less, that the poor may have it so much cheaper.

This operates then as a tax for the maintenance of the poor. A very good thing, you will say. But I ask, why a partial tax? Why laid on us farmers only? If it be a good thing, pray, Messieurs the Public, take your share of it, by indemnifying us a little out of your public treasury. In doing a good thing, there is both honor and pleasure;—you are welcome to your share of both.

For my own part, I am not so well satisfied of the goodness of this thing. I am for doing good to the poor, but I differ in opinion about the means. I think the best way of doing good to the poor, is not making them easy *in* poverty, but leading or driving them *out* of it. In my youth I travelled much, and I observed in different countries, that

the more public provisions were made for the poor, the less they provided for themselves, and of course became poorer. And, on the contrary, the less was done for them, the more they did for themselves, and became richer. There is no country in the world where so many provisions are established for them; so many hospitals to receive them when they are sick or lame, founded and maintained by voluntary charities; so many alms-houses for the aged of both sexes; together with a solemn general law, made by the rich, to subject their estates to a heavy tax for the support of the poor. Under all these obligations, are our poor modest, humble, and thankful? and do they use their best endeavors to maintain themselves, and lighten our shoulders of this burthen? On the contrary, I affirm that there is no country in the world in which the poor are more idle, dissolute, drunken, and insolent. The day you passed that act, you took away from before their eyes the greatest of all inducements to industry, frugality, and sobriety, by giving them a dependence on somewhat else than a careful accumulation during youth and health, for support in age or sickness. In short, you offered a premium for the encouragement of idleness, and you should not now wonder that it has had its effect in the increase of poverty. Repeal that law, and you will soon see a change in their manners—*Saint Monday* and *Saint Tuesday* will soon cease to be holi-

days. SIX *days shalt thou labor*, though one of the old commandments, long treated as out of date, will again be looked upon as a respectable precept; industry will increase, and with it plenty among the lower people; their circumstances will mend, and more will be done for their happiness by inuring them to provide for themselves, than could be done by dividing all your estates among them.

Excuse me, Messieurs the Public, if upon this *interesting* subject I put you to the trouble of reading a little of *my* nonsense: I am sure I have lately read a great deal of *yours*; and therefore from you (at least from those of you who are writers) I deserve a little indulgence.

I am yours, &c. ARATOR.[1]

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[1] The late Mr. Owen Ruffhead being some time ago employed in preparing a *Digest of our Poor Laws*, communicated a copy of it to Dr. Franklin, for his advice. Dr. Franklin recommended that provision should be made therein, for the printing on a sheet of paper and dispersing, in each parish in the kingdom, annual accounts of every disbursement and receipt of its officers. It is obvious to remark how greatly this must tend to check both the officers and the poor, and to *inform* and interest the parishioners with respect to parish concerns. Some of the American colonies actually practise this measure with a success which might justify its adoption here. [England.]

Later improvements, however, in the English poor laws, have not only been meditated, but attempted. In particular, in 1773, an act of parliament was proposed, in order to invite the poor to set apart money for the purchase of annuities, in all

parishes and townships managing the poor's-rate, that could admit of, and would formally consent to the regulation. Some of the particulars of this scheme were as follows. The annuities, which to accommodate the poor were payable quarterly, were in no case to exceed 20*l*., and no principal purchase-money was to be received of less amount than 5*l*. at a time; the parties might choose any age for the purchase between 15 and 75, but they could not receive the annuity before 50, if men, and 35, if women, the annuity in the mean time increasing in proportion as they had waited; the annuities also could not knowingly be granted to any but those entitled to legal parish settlements, nor for any other lives than those of the grantees; though they were saleable, provided the first refusal of them was offered to the grantors. The proper officers of the parish or township (who were constituted the grantors), in order to effect these purposes, were to be erected into a corporation with a seal; the grants (which were framed according to a prescribed and cheap form, and protected from frauds) were to be in several ways authenticated and preserved; the annuities were to be taken up in some parliamentary fund, after the rate of 3 per cent. interest, negociable at the bank of England; and the accounts, after being properly kept and signed, were to be annually audited and recorded with the justices at the quarter-sessions. The relief to the poor, in case of delay of payment, was summary, and almost instant; but in return, the corporation might receive gifts and legacies, and have the benefit of all neglected annuities, to the easing of the poor's-rate; besides other advantages given them by the calculations, particularly that arising from a low standard of interest, which necessarily rendered the terms of the annuity in proportion dearer to the poor. It was thought that domestic use and economy were concerned, in thus rescuing somewhat from profligacy and unhealthy debauchery, in applying the surplus of health and of strength to the relief of the penury and infirmities of age, and in promoting good habits; yet without depriving the state of

the whole of effectual labor, or leaving it incumbered with the charge of individuals, who might assist themselves. But this scheme, which was proposed by Baron Maseres, regulated and superintended as to the calculations by Dr. Price, and supported by Sir George Savile and Mr. Dowdeswell, only passed the commons: it was rejected by the lords; chiefly because the landed interest there was alarmed at the poor's-rate being made the security for the annuities, in case of deficiency in the funds.

However, the burthen of the poor's-rate was still felt too considerable not to demand inquiry; and an act soon passed, calling for a general abstract of the returns made by the overseers of the poor. It appeared in consequence, that there were—

	Totals raised by the poor's-rate, from Easter 1775, to Easter 1776.	Of which there was expended on the poor alone,
In England	1,679,585*l.*	1,523,164*l.*
And in Wales	40,732*l.*	33,641*l.*
	1,720,317*l.*	1,556,805*l.*

The remainder of the sum raised was applied to county uses, except about 26,000*l.* which seems not to have been brought into the year's account. Nearly one-twentieth of the enormous sum expended on the poor, was for the single article of rent; and the litigations concerning settlements, and the removal of paupers, made another article of nearly half the same amount. In Davenant we find an estimate of the poor's-rate, made towards the latter end of Charles the Second's reign, by a reasonable medium, as he states, of several years:—

The gross sums are,	For England	631,609*l.*
	And for Wales	33,753*l.*
		665,362*l.*

So that while the poor's rate of Wales has remained in a manner stationary for this period, that of England does not fall much short of being trebled.

ON SMUGGLING, AND ITS VARIOUS SPECIES.[1]

SIR,

THERE are many people that would be thought, and even think themselves, *honest* men, who fail nevertheless in particular points of honesty; deviating from that character sometimes by the prevalence of mode or custom, and sometimes through mere inattention; so that their *honesty* is partial only, and not *general* or universal. Thus, one who would scorn to over-reach you in a bargain, shall make no scruple of tricking you a little now and then at cards; another that plays with the utmost fairness, shall with great freedom cheat you in the sale of a horse. But there is no kind of dishonesty, into which otherwise good people more easily and frequently fall, than that of defrauding government of its revenues by smuggling when they have an opportunity, or encouraging smugglers by buying their goods.

Since the year 1776, no farther public measures seem to have been taken respecting the regulation of the poor. (*Written in* 1779.)

(See, on the above subjects, the proposed act of parliament, with the annexed tables and instructions, printed for Eyre and Strahan; also the Abstract of the Returns of the Poor's-rate, printed for ditto; Dr. Price on Payments, 3d. edit. p. 115; and Whitworth's Davenant, vol. i. p. 39.) B.V.

[1] This letter is extracted from the *London Chronicle* for November 24, 1767; and is addressed to the printer of that newspaper.

I fell into these reflections the other day, on hearing two gentlemen of reputation discoursing about a small estate, which one of them was inclined to sell, and the other to buy; when the seller, in recommending the place, remarked, that its situation was very advantageous on this account, that being on the sea-coast in a smuggling country, one had frequent opportunities of buying many of the expensive articles used in a family, (such as tea, coffee, chocolate, brandy, wines, cambrics, Brussels laces, French silks, and all kinds of India goods,) 20, 30, and in some articles 50 *per cent.* cheaper than they could be had in the more interior parts, of traders that paid duty. The other *honest* gentleman allowed all this to be an advantage, but insisted that the seller, in the advanced price he demanded on that account, rated the advantage much above its value. And neither of them seemed to think dealing with smugglers, a practice that an *honest* man (provided he got his goods cheap) had the least reason to be ashamed of.

At a time when the load of our public debt, and the heavy expense of maintaining our fleets and armies to be ready for our defence on occasion, makes it necessary not only to continue old taxes, but often to look out for new ones; perhaps it may not be unuseful to state this matter in a light that few seem to have considered it in.

The people of Great Britain, under the happy constitution of this country, have a privilege few other countries enjoy, that of choosing the third branch of the legislature; which branch has alone the power of regulating their taxes. Now whenever the government finds it necessary for the common benefit, advantage, and safety of the nation, for the security of our liberties, property, religion, and every thing that is dear to us, that certain sums shall be yearly raised by taxes, duties, &c. and paid into the public treasury, thence to be dispensed by government for those purposes, ought not every *honest man* freely and willingly to pay his just proportion of this necessary expense? Can he possibly preserve a right to that character, if by any fraud, stratagem, or contrivance, he avoids that payment in whole or in part?

What should we think of a companion, who having supped with his friends at a tavern, and partaken equally of the joys of the evening with the rest of us, would nevertheless contrive, by some artifice, to shift his share of the reckoning upon others, in order to go off scot-free? If a man who practised this, would, when detected, be deemed and called a scoundrel, what ought he to be called, who can enjoy all the inestimable benefits of public society, and yet by smuggling, or dealing with smugglers, contrive to evade paying his just share of the expense, as settled by his own representatives in parliament; and wrongfully

throw it upon his honester and perhaps much poorer neighbors? He will perhaps be ready to tell me, that he does not wrong his neighbors; he scorns the imputation; he only cheats the king a little, who is very able to bear it. This however is a mistake. The public treasure is the treasure of the nation, to be applied to national purposes. And when a duty is laid for a particular public and necessary purpose, if through smuggling that duty falls short of raising the sum required, and other duties must therefore be laid to make up the deficiency; all the additional sum laid by the new duties and paid by other people, though it should amount to no more than a halfpenny or a farthing per head, is so much actually picked out of the pockets of those other people by the smugglers and their abettors and encouragers. Are they then any better or other than pickpockets? and what mean, low, rascally pickpockets must those be, that can pick pockets for halfpence and for farthings?

I would not however be supposed to allow in what I have just said, that cheating the king is a less offence against honesty, than cheating the public. The king and the public in this case are different names for the same thing; but if we consider the king distinctly, it will not lessen the crime: it is no justification of a robbery, that the person robbed was rich and able to bear it. The king has as much right to justice as the meanest

of his subjects; and as he is truly the common *father* of his people, those that rob him fall under the scripture woe, pronounced against the son *that robbeth his father, and saith it is no sin.*

Mean as this practice is, do we not daily see people of character and fortune engaged in it for trifling advantages to themselves? Is any lady ashamed to request of a gentleman of her acquaintance, that when he returns from abroad, he would smuggle her home a piece of silk or lace from France or Flanders? Is any gentleman ashamed to undertake and execute the commission? Not in the least. They will talk of it freely, even before others whose pockets they are thus contriving to pick by this piece of knavery.

Among other branches of the revenue, that of the post-office is, by a late law, appropriated to the discharge of our public debt, to defray the expenses of the state. None but members of parliament, and a few public officers, have now a right to avoid, by a frank, the payment of postage. When any letter not written by them or on their business, is franked by any of them, it is a hurt to the revenue; an injury which they must now take the pains to conceal by writing the whole superscription themselves. And yet such is our insensibility to justice in this particular, that nothing is more common than, to see, even in a reputable company, a *very honest* gentleman or lady declare, his or her intention to cheat the nation of three-

pence by a frank; and, without blushing, apply to one of the very legislators themselves, with a modest request, that he would be pleased to become an accomplice in the crime, and assist in the perpetration.

There are those who by these practices take a great deal in a year out of the public purse, and put the money into their own private pockets. If, passing through a room where public treasure is deposited, a man takes the opportunity of clandestinely pocketing and carrying off a guinea, is he not truly and properly a thief? And if another evades paying into the treasury a guinea he ought to pay in, and applies it to his own use, when he knows it belongs to the public as much as that which has been paid in, what difference is there in the nature of the crime, or the baseness of committing it?

Some laws make the receiving of stolen goods equally penal with stealing, and upon this principle, that if there were no receivers there would be few thieves. Our proverb too, says truly, that *the receiver is as bad as the thief.* By the same reasoning, as there would be few smugglers, if there were none who knowingly encouraged them by buying their goods, we may say that the encouragers of smuggling are as bad as the smugglers; and that as smugglers are a kind of thieves, both equally deserve the punishments of thievery.

In this view of wronging the revenue, what

must we think of those who can evade paying for their wheels and their plate, in defiance of law and justice, and yet declaim against corruption and peculation, as if their own hands and hearts were pure and unsullied? The Americans offend us grievously, when, contrary to our laws, they smuggle goods into their own country; and yet they had no hand in making those laws. I do not however pretend from thence to justify them: but I think the offence much greater in those who either directly or indirectly have been concerned in making the very laws they break. And when I hear them exclaiming against the Americans, and for every little infringement of the acts of trade, or obstruction given by a petty mob to an officer of our customs in that country, calling for vengeance against the whole people as REBELS and TRAITORS, I cannot help thinking there are still those in the world who can *see a mote in their brother's eye, while they do not discern a beam in their own;* and that the old saying is as true now as ever it was, *one man may better steal a horse, than another look over the hedge.* B. F.

OBSERVATIONS ON WAR.

By the original law of nations, war and extirpation were the punishment of injury. Humanising by degrees, it admitted slavery instead of death: a farther step was, the exchange of pri-

soners instead of slavery; another, to respect more the property of private persons under conquest, and be content with acquired dominion. Why should not this law of nations go on improving? Ages have intervened between its several steps; but as knowledge of late increases rapidly, why should not those steps be quickened? Why should it not be agreed to, as the future law of nations, that in any war hereafter the following description of men should be undisturbed, have the protection of both sides, and be permitted to follow their employments in security? viz.

1. Cultivators of the earth, because they labor for the subsistence of mankind.

2. Fishermen, for the same reason.

3. Merchants and traders in unarmed ships, who accommodate different nations by communicating and exchanging the necessaries and conveniences of life.

4. Artists and mechanics, inhabiting and working in open towns.

It is hardly necessary to add, that the hospitals of enemies should be unmolested—they ought to be assisted. It is for the interest of humanity in general, that the occasions of war, and the inducements to it, should be diminished. If rapine be abolished, one of the encouragements to war is taken away; and peace therefore more likely to continue and be lasting.

The practice of robbing merchants on the high seas—a remnant of the ancient piracy—though it may be accidentally beneficial to particular persons, is far from being profitable to all engaged in it, or to the nation that authorises it. In the beginning of a war some rich ships are surprised and taken. This encourages the first adventurers to fit out more armed vessels; and many others to do the same. But the enemy at the same time become more careful; arm their merchant ships better, and render them not so easy to be taken: they go also more under the protection of convoys. Thus, while the privateers to take them are multiplied, the vessels subject to be taken, and the chances of profit, are diminished; so that many cruises are made wherein the expenses overgo the gains; and, as is the case in other lotteries, though particulars have got prizes, the mass of adventurers are losers, the whole expense of fitting out all the privateers during a war, being much greater than the whole amount of goods taken.

Then there is the national loss of all the labor of so many men during the time they have been employed in robbing; who besides spend what they get in riot, drunkenness, and debauchery; lose their habits of industry; are rarely fit for any sober business after a peace, and serve only to increase the number of highwaymen and housebreakers. Even the undertakers who have been fortunate, are, by sudden wealth, led into expen-

sive living, the habit of which continues when the means of supporting it cease, and finally ruins them; a just punishment for their having wantonly and unfeelingly ruined many honest, innocent traders and their families, whose substance was employed in serving the common interest of mankind.

ON THE LABORING POOR.

To the Editor of * * * April, 1768.

Sir,

I have met with much invective in the papers for these two years past, against the hard-heartedness of the rich, and much complaint of the great oppressions suffered in this country by the laboring poor. Will you admit a word or two on the other side of the question? I do not propose to be an advocate for oppression or oppressors. But when I see that the poor are, by such writings, exasperated against the rich, and excited to insurrections, by which much mischief is done, and some forfeit their lives, I could wish the true state of things were better understood, the poor not made by these busy writers more uneasy and unhappy than their situation subjects them to be, and the nation not brought into disrepute among foreigners, by public groundless accusations of ourselves, as if the rich in England had no com-

passion for the poor, and Englishmen wanted common humanity.

In justice, then, to this country, give me leave to remark, that the condition of the poor here is, by far, the best in Europe; for that, except in England and her American colonies, there is not in any country of the known world, not even in Scotland or Ireland, a provision by law to enforce a support of the poor. Everywhere else necessity reduces to beggary. This law was not made by the poor. The legislators were men of fortune. By that act they voluntarily subjected their own estates, and the estates of all others, to the payment of a tax, for the maintenance of the poor, incumbering those estates with a kind of rent charge for that purpose, whereby the poor are vested with an inheritance, as it were, in all the estates of the rich. I wish they were benefitted by this generous provision, in any degree equal to the good intention with which it was made, and is continued. But I fear the giving mankind a dependance on any thing for support, in age or sickness, besides industry and frugality during youth and health, tends to flatter our natural indolence, to encourage idleness and prodigality, and thereby to promote and increase poverty, the very evil it was intended to cure; thus multiplying beggars instead of diminishing them.

Besides this tax, which the rich in England have subjected themselves to in behalf of the poor,

amounting in some places to five or six shillings in the pound, of the annual income, they have, by donations and subscriptions, erected numerous schools in various parts of the kingdom, for educating, gratis, the children of the poor, in reading and writing; and in many of those schools the children are also fed and clothed. They have erected hospitals at an immense expense, for the reception and cure of the sick, the lame, the wounded, and the insane poor, for lying-in women, and deserted children. They are also continually contributing towards making up losses occasioned by fire, by storms, or by floods, and to relieve the poor in severe seasons of frost, in times of scarcity, &c. in which benevolent and charitable contributions no nation exceeds us.—Surely, there is some gratitude due for so many instances of goodness.

Add to this all the laws made to discourage foreign manufactures, by laying heavy duties on them, or totally prohibiting them, whereby the rich are obliged to pay much higher prices for what they wear and consume, than if the trade was open. These are so many laws for the support of our laboring poor, made by the rich, and continued at their expense: all the difference of price between our own and foreign commodities, being so much given by our rich to our poor; who would indeed be enabled by it to get by degrees above poverty, if they did not, as too generally they do, consider every increase of wages, only as some-

thing that enables them to drink more and work less; so that their distress in sickness, age, or times of scarcity, continues to be the same as if such laws had never been made in their favor.

Much malignant censure have some writers bestowed upon the rich for their luxury and expensive living, while the poor are starving, &c.; not considering that what the rich expend, the laboring poor receive in payment for their labor. It may seem a paradox if I should assert, that our laboring poor do in every year receive *the whole revenue of the nation*; I mean not only the public revenue, but also the revenue or clear income of all private estates, or a sum equivalent to the whole.—In support of this position I reason thus: the rich do not work for one another. Their habitations, furniture, clothing, carriages, food, ornaments, and every thing, in short, that they or their families use and consume, is the work or produce of the laboring poor, who are and must be continually paid for their labor in producing the same. In these payments the revenues of private estates are expended, for most people live up to their incomes. In clothing or provision for troops, in arms, ammunition, ships, tents, carriages, &c. &c. (every particular the produce of labor), much of the public revenue is expended. The pay of officers, civil and military, and of the private soldiers and sailors, requires the rest; and they spend that also in paying for what is produced by the laboring poor. I

allow that some estates may increase by the owners spending less than their income; but then I conceive that other estates do at the same time diminish, by the owners spending more than their income, so that when the enriched want to buy more land, they easily find lands in the hands of the impoverished, whose necessities oblige them to sell; and thus this difference is equalled. I allow also that part of the expense of the rich is in foreign produce or manufactures, for producing which the laboring poor of other nations must be paid; but then I say, we must first pay our own laboring poor for an equal quantity of our manufactures or produce to exchange for those foreign productions, or we must pay for them in money, which money not being the natural produce of our country, must first be purchased from abroad, by sending out its value in the produce or manufactures of this country, for which manufactures our laboring poor are to be paid. And indeed if we did not export more than we import, we could have no money at all. I allow farther, that there are middle men, who make a profit, and even get estates, by purchasing the labor of the poor, and selling it at advanced prices to the rich; but then they cannot enjoy that profit, or the incomes of estates, but by spending them in employing and paying our laboring poor, in some shape or other, for the products of industry.—Even beggars, pensioners, hospitals, and all that are supported by charity, spend their

incomes in the same manner. So that finally, as I said at first, *our laboring poor receive annually the whole of the clear revenues of the nation*, and from us they can have no more.

If it be said that their wages are too low, and that they ought to be better paid for their labor, I heartily wish that any means could be fallen upon to do it consistent with their interest and happiness; but as the cheapness of other things is owing to the plenty of those things, so the cheapness of labor is in most cases owing to the multitude of laborers, and to their under-working one another in order to obtain employment. How is this to be remedied? A law might be made to raise their wages; but if our manufactures are too dear, they will not vend abroad, and all that part of employment will fail, unless by fighting and conquering, we compel other nations to buy our goods whether they will or no, which some have been mad enough at times to propose. Among ourselves, unless we give our working people less employment, how can we for what they do pay them higher than we do? Out of what fund is the additional price of labor to be paid, when all our present incomes are, as it were, mortgaged to them? Should they get higher wages, would that make them less poor, if in consequence they worked fewer days of the week proportionably? I have said a law might be made to raise their wages; but I doubt much whether it could be executed to any purpose, un-

less another law, now indeed almost obsolete, could at the same time be revived and enforced; a law, I mean, that many have often heard and repeated, but few have ever duly considered. SIX *days shalt thou labor*. This is as positive a part of the commandment, as that which says, *the* SEVENTH *day thou shalt rest;* but we remember well to observe the indulgent part, and never think of the other. *St. Monday* is generally as duly kept by our working people as *Sunday;* the only difference is, that instead of employing their time cheaply at church, they are wasting it expensively at the ale-house. I am, Sir, yours, &c.

MEDIUS.

PLAN FOR BENEFITING DISTANT UNPROVIDED COUNTRIES.

By Messrs. Franklin and Dalrymple.

Aug. 29, 1771.

THE country called in the maps *New Zealand*, has been discovered by the *Endeavour*, to be two islands, together as large as *Great Britain:* these islands, named *Acpy-nomawée* and *Tovy-poennammoo*,

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[1] These proposals were printed upon a sheet of paper, and distributed. The parts written by Dr. Franklin and Mr. Dalrymple are easily distinguished.

are inhabited by a brave and generous race, who are destitute of *corn, fowls,* and *all quadrupeds,* except *dogs.*

These circumstances being mentioned lately in a company of men of liberal sentiments, it was observed that it seemed *incumbent* on such a country as *this,* [England] to communicate to *all others* the conveniencies of life which we enjoy.

Dr. Franklin, whose life has ever been directed to promote the true interest of society, said, "he would with all his heart *subscribe* to a voyage intended to communicate *in general* those benefits which we enjoy, to countries destitute of them in the remote parts of the globe." This proposition being warmly adopted by the rest of the company, Mr. Dalrymple, then present, was induced to offer to undertake the command on such an expedition.

On mature reflection this scheme appears the more honorable to the national character of any which can be conceived, as it is grounded on the noblest principle of benevolence. Good intentions are often frustrated by letting them remain indigested; on this consideration Mr. Dalrymple was induced to put the outlines on paper, which are now published, that by an early communication there may be a better opportunity of collecting all the hints which can conduce to execute effectually the benevolent purpose of the expedition, in case it should meet with general approbation.

On this scheme being shown to Dr. Franklin,

he communicated his sentiments by way of introduction, to the following effect.

"Britain is said to have produced originally nothing but *sloes.* What vast advantages have been communicated to her by the fruits, seeds, roots, herbage, animals, and arts of other countries! We are by their means become a wealthy and a mighty nation, abounding in all good things. Does not some *duty* hence arise from us towards other countries still remaining in our former state?

"Britain is now the first maritime power in the world. Her ships are innumerable, capable by their form, size, and strength, of sailing all seas. Our seamen are equally bold, skilful and hardy; dexterous in exploring the remotest regions, and ready to engage in voyages to unknown countries, though attended with the greatest dangers. The inhabitants of those countries, our *fellow men,* have canoes only; not knowing iron, they cannot build ships: they have little astronomy, and no knowledge of the compass to guide them: they cannot therefore come to us, or obtain any of our advantages. From these circumstances, does not some duty seem to arise from us to them? Does not Providence by these distinguishing favors seem to call on us to do something ourselves for the common interest of humanity?

"Those who think it their duty to ask bread and other blessings daily from heaven, would they not think it equally a duty to communicate of those

blessings when they have received them; and show their gratitude to their great Benefactor by the only means in their power, promoting the happiness of his other children?

"*Ceres* is said to have made a journey through many countries to teach the use of corn, and the art of raising it. For this single benefit the grateful nations deified her. How much more may Englishmen deserve such honor, by communicating the knowledge and use not of corn only, but of all the other enjoyments earth can produce, and which they are now in possession of. *Communiter bona profundere, Deûm est.*

"Many voyages have been undertaken with views of profit or of plunder, or to gratify resentment; to procure some advantage to ourselves, or do some mischief to others: but a voyage is now proposed to visit a distant people on the other side the globe; not to cheat them, not to rob them, not to seize their lands, or enslave their persons; but merely to do them good, and make them, as far as in our power lies, to live as comfortably as ourselves.

"It seems a laudable wish that all the nations of the earth were connected by a knowledge of each other, and a mutual exchange of benefits: but a commercial nation particularly should wish for a general civilisation of mankind, since trade is always carried on to much greater extent with people who have the arts and conveniencies of life, than it can be with naked savages. We may there-

fore hope in this undertaking to be of some service to our country, as well as to those poor people who, however distant from us, are in truth related to us, and whose interests do, in some degree, concern every one who can say *Homo sum*," &c.

Scheme of a voyage by subscription, to convey the conveniencies of life, as fowls, hogs, goats, cattle, corn, iron, &c. to those remote regions which are destitute of them, and to bring from thence such productions as can be cultivated in this kingdom to the advantage of society, in a ship under the command of Alexander Dalrymple.

Catt or bark, from the coal trade, of 350 tons, estimated at about - - - - - - - - -	£2000
Extra expenses, stores, boats, &c. - - - -	3000
	5000

To be manned with 60 men at
4*l.* per man per month

240
12

2880 per annum
3

Wages and provisions	8640 for three years - - -	8640
		13640
Cargo included, supposed - - - - - - - -		*l.*15000

The expenses of this expedition are calculated for *three* years; but the greatest part of the amount of wages will not be wanted till the ship returns, and a great part of the expense of provisions will be saved by what is obtained in the course of the voyage by barter or otherwise, though it is proper to make provision for contingencies.

* * * * * * *

ON THE INSTITUTION IN HOLLAND TO PREVENT POVERTY.

" *Craven Street, June 17th,* 1772.

" To Mr. Maséres,

" Sir,

" I thank you for the pamphlet proposing to establish Life Annuities in parishes, &c.: I think it an excellent one. In compliance with your wish, page 25, 26, I send it back with a few marginal notes (perhaps of no great importance) made in reading it, requesting it may be returned to me.

" In page 118 of Dr. Price's Book on Annuities, second edition, you will find mention made of an institution in Holland. He had that information from me. Those houses are handsome neat buildings with very comfortable apartments; some form the sides of a square, with glass plats and gravel walks, flowers, &c., and some have little separate gardens behind each apartment. Those for men are called *Oude Mannen Hayzen,* for women *Oude*

Vrouwen Hayzen. I think the different kinds sometimes make different sides of the same square. There is a chapel for prayers, a common kitchen, and a common hall, in which they dine together. Two persons such as best like one another, and choose so to associate, are generally lodged in one apartment, though in separate beds, that they may be at hand to assist each other in case of sudden illness in the night, and otherwise be mutually helpful. The directors have also a room to meet in, who form rules for the government of the house, hear complaints, and rectify what is amiss. Gentlemen are directors of the *Oude Mannen Haus*, ladies of the *Oude Vrouwen Haus.* A committee of two are chosen every year, who visit often, see the rules observed, and take care of the management. At the end of the year, these are thanked off, and as an honorable memorial of their service, their names, with the year they served, are added to the gold-letter list on the walls of the room. All the furniture is neat and convenient, the beds and rooms kept clean and sweet by the servants of the house, and the people appear to live happily.

"These institutions seem calculated to *prevent* poverty, which is rather a better thing than *relieving* it: for it keeps always *in the public eye* a state of comfort and repose, with freedom from care in old age, held forth as an encouragement to so much industry and frugality in youth as may at least

serve to raise the required sum (suppose 50*l.*) that is to intitle a man or woman at 50 to a retreat in these houses. And in acquiring this sum, habits may be acquired that produce such affluence before this age arrives, as to make the retreat unnecessary, and so never claimed. Hence if 50*l.* would (as by your table) intitle a man at 50 years of age to an annuity of 19*l.* 3*s.* 6*d*½., I suppose that in such a house, entertainment and accommodation to a much greater value might be afforded him, because the right to live there is not transferable, and therefore every unclaimed right is an advantage to the house, while annuities would probably be all claimed. Then it seems to me that the prospect of a distant annuity will not be so influencing on the minds of young people as the constant view of the comfort enjoyed in those houses, in comparison of which, even the payment and *receipt* of the annuities are *private transactions.*

"I write this in hopes you will, after consideration, favor me with your opinion whether (in addition to your plan, which will still have all its advantages for smaller sums) one or more such houses in every county would not probably be of great use in still further promoting industry and frugality among the lower people, and of course lessening the enormous weight of the poor tax?

"I enclose a little piece I wrote in America to encourage and strengthen those important virtues,

of which I beg your acceptance, and am, with great esteem,

"Sir, your most obedient humble servant,

"B. FRANKLIN."

POSITIONS TO BE EXAMINED.

1. All food or subsistence for mankind arise from the earth or waters.

2. Necessaries of life that are not foods, and all other conveniencies, have their values estimated by the proportion of food consumed while we are employed in procuring them.

3. A small people with a large territory may subsist on the productions of nature, with no other labor than that of gathering the vegetables and catching the animals.

4. A large people with a small territory finds these insufficient, and to subsist, must labor the earth, to make it produce greater quantities of vegetable food, suitable for the nourishment of men, and of the animals they intend to eat.

5. From this labor arises a *great increase* of vegetable and animal food, and of materials for clothing, as flax, wool, silk, &c. The superfluity of these is wealth. With this wealth we pay for the labor employed in building our houses, cities, &c. which are therefore only subsistence thus metamorphosed.

6. *Manufactures* are only *another shape* into which so much provisions and subsistence are turned, as were *equal in value* to the manufactures produced. This appears from hence, that the manufacturer does not, in fact, obtain from the employer for his labor, *more* than a mere subsistence, including raiment, fuel, and shelter; all which derive their value from the provisions consumed in procuring them.

7. The produce of the earth, thus converted into manufactures, may be more easily carried to distant markets than before such conversion.

8. *Fair commerce* is, where equal values are exchanged for equal, the expense of transport included. Thus if it costs A in *England* as much labor and charge to raise a bushel of wheat, as it costs B in *France* to produce four gallons of wine, then are four gallons of wine the fair exchange for a bushel of wheat, A and B meeting at half distance with their commodities to make the exchange. The advantage of this fair commerce is, that each party increases the number of his enjoyments, having, instead of wheat alone, or wine alone, the use of both wheat and wine.

9. Where the labor and expense of producing both commodities are known to both parties, bargains will generally be fair and equal. Where they are known to one party only, bargains will often be unequal, knowledge taking its advantage of ignorance.

10. Thus he that carries 1000 bushels of wheat abroad to sell, may not probably obtain so great a profit thereon as if he had first turned the wheat into manufactures, by subsisting therewith the workmen while producing those manufactures: since there are many expediting and facilitating methods of working, not generally known; and strangers to the manufactures, though they know pretty well the expense of raising wheat, are unacquainted with those short methods of working, and thence being apt to suppose more labor employed in the manufactures than there really is, are more easily imposed on in their value, and induced to allow more for them than they are honestly worth.

11. Thus the advantage of having manufactures in a country does not consist, as is commonly supposed, in their highly advancing the value of rough materials, of which they are formed; since, though six-pennyworth of flax may be worth 20*s.* when worked into lace, yet the very cause of its being worth 20*s.* is, that besides the flax, it has cost 19*s.* 6*d.* in subsistence to the manufacturer. But the advantage of manufactures is, that under their shape provisions may be more easily carried to a foreign market; and by their means our traders may more easily cheat strangers. Few, where it is not made, are judges of the value of lace. The importer may demand forty, and perhaps get thirty shillings for that which cost him but twenty.

12. Finally, there seem to be but three ways for a nation to acquire wealth. The first is by *war*, as the *Romans* did, in plundering their conquered neighbors. This is *robbery*.—The second by *commerce*, which is, generally, *cheating*.—The third by *agriculture*, the only *honest way*; wherein man receives a real increase of the seed thrown into the ground, in a kind of continual miracle wrought by the hand of God in his favor, as a reward for his innocent life, and his virtuous industry. B. F.

April 4, 1769.

PROVISION MADE IN CHINA AGAINST FAMINE.

Extract of a Letter to Dr. Percival.

I have somewhere read that in China an account is yearly taken of the number of people, and the quantities of provision produced. This account is transmitted to the Emperor, whose ministers can thence foresee a scarcity likely to happen in any province, and from what province it can best be supplied in good time. To facilitate the collecting of this account, and prevent the necessity of entering houses and spending time in asking and answering questions, each house is furnished with a little board to be hung without the door, during a certain time each year; on which board are marked certain words, against which the inhabitant is to mark number or quantity, somewhat in this manner:

Men,
Women,
Children,
Rice or Wheat,
Flesh, &c.

All under 16 are accounted children, and all above, men and women. Any other particulars which the government desires information of, are occasionally marked on the same boards. Thus the officers appointed to collect the accounts in each district, have only to pass before the doors, and enter into their book what they find marked on the board, without giving the least trouble to the family. There is a penalty on marking falsely, and as neighbors must know nearly the truth of each other's account, they dare not expose themselves by a false one, to each other's accusation. Perhaps such a regulation is scarcely practicable with us.[1]

NOTE RESPECTING TRADE AND MANUFACTURES.

Suppose a country, X, with three manufactures, as *cloth*, *silk*, *iron*, supplying three other countries, A, B, C, but is desirous of increasing the vent, and

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[1] The above passage is taken from Dr. Percival's Essays, Vol. III. p. 25, being an extract from a letter written to him by Dr. Franklin, on the subject of his observations on the state of population in Manchester and other adjacent places. B. V.

raising the price of cloth in favor of her own clothiers.

In order to this, she forbids the importation of foreign cloth from A.

A, in return, forbids silks from X.

Then the silk-workers complain of a decay of trade.

And X, to content them, forbids silks from B.

B, in return, forbids iron-ware from X.

Then the iron-workers complain of decay.

And X forbids the importation of iron from C.

C, in return, forbids cloth from X.

What is got by all these prohibitions?

Answer.—All four find their common stock of the enjoyments and conveniencies of life diminished.

London, July 7, 1767. B. F.

NOTIONS CONCERNING TRADE AND MERCHANTS.

1. Were it possible for men, remote from each other, to know easily one another's wants and abundances, and practicable for them on all occasions conveniently to meet and make fair exchanges of their respective commodities, there would then be no use of the middle man or merchant; such a profession would not exist.

2. But since that is not possible, were all governments to appoint a number of public officers, whose

duty and business it should be to inform themselves thoroughly of those wants and abundances, and to procure, by proper management, all the exchanges that would tend to increase the general happiness, such officers, if they could well discharge their trust, would deserve honors and salaries equivalent to their industry and fidelity.

3. But, as in large communities, and for the more general occasions of mankind, such officers have never been appointed, perhaps from a conviction that it would be *impracticable* for such an appointment effectually to answer its purpose, it seems necessary to permit men, who, for the *possible profits* in prospect, will undertake it, to fetch and carry, at all distances, the produce of other men's industry, and thereby assist those useful exchanges.

4. As the persons primarily interested in these exchanges cannot conveniently meet to make known their wants and abundances, and to bargain for exchanges, those who transport the goods should be interested to study the probability of these wants, and where to find the means of supplying them; and, since there exist no salaries or public rewards for them in proportion to their skill, industry, and utility to the people in general, nor to make them any compensation for their losses arising from inexpertness or from accident, it seems reasonable that for their encouragement to follow the business, they should be left to make such profits by it as they can, which, where it is open to all, will

probably seldom be extravagant. And perhaps by this means the business will be better done for the general advantage, and those who do it more properly rewarded according to their merits, than would be the case were special officers to be appointed for that service.

[The Essay that follows was originally published in 1774, and is the joint work of George Whately and Dr. Franklin. The original work was indeed written by the former, and communicated to the latter, who rarely ever perused a literary production without correcting, improving, or augmenting its force and value, from his own sources. The corrections and additions which were made by Dr. Franklin, produced an amicable controversy between them, who had the best claim to call himself the author of it, which was closed by a determination to publish it, without any name, but under this designation—"By a well-wisher to the king and country." Dr. Franklin, who was never so solicitous about the reputation as about the practical utility of his writings, continued to consider his friend, Mr. Whately, as the author, and persisted even to the last in that sentiment; for in a letter of the 21st of August, 1784, from Paris, addressed to him in the words, "*My dear old Friend,*" he requests a copy of his excellent little work--"The Principles of Trade."[1] The whole work is given here, because with whatever success the separation might be accomplished, of what belongs to the one or the other, the separate parts would be each incomplete, and the whole is particularly worthy preservation.]

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[1] See Private Correspondence, Part I.

PRINCIPLES OF TRADE.

Freedom and Protection are its best support; Industry the only means to render Manufactures cheap.

Of Coins, Exchange, and Bounties, particularly the Bounty on Coin.

Commerce is generally understood to be the basis on which the power of this country hath been raised, and on which it must ever stand.

Tous les sujets doivent leurs soins, et leurs lumières, à l'état.

DEDICATION.

To all those who have the welfare and prosperity of these kingdoms at heart, the following Essay, containing, we hope, useful and incontrovertible principles on the subjects treated of, is very heartily and affectionately inscribed.

March, 1774.

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PREFACE.

It is a vain imagination that we exist only for ourselves, or our particular country. The all-wise Creator has ordained that *a mutual dependence* shall run through all his works; and though our limited capacities will not admit us fully to comprehend the nature and end of this connected chain of things, yet we may, and indeed ought, to inquire into and consider every thing which relates to our mutual dependence upon one another, and the springs and principles of our actions.

By this investigation we shall find that our wants, whether real or ideal, our passions, and our habits, are the springs of all our actions, and indeed the movers of the general intercourse and commerce between one man and another, one country and another.

Most writers upon trade have made it their business to support and explain some particular branches of traffic, or some favorite hypothesis. We shall, in the ensuing essay, use our best endeavors to remove from the friends of trade, and mankind in general, some prevailing prejudices, and to treat in a concise manner, upon a few self-evident principles and general maxims, under a persuasion,

that if such maxims and principles are just, all deductions and discussions whatever may be tried by their standard.

Some very respectable friends have indulged us with their ideas and opinions. It is with the greatest pleasure we, in this second edition, most gratefully acknowledge the favor; and must add, that should the public hold this performance in any estimation, no small share belongs to those friends.

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§ 1. Trade or commerce is the intercourse, as well between nation and nation, as between one man and another; by which we acquire whatsoever may be thought, or understood to be, of use or delight, whether real or ideal.

2. The spring or movement of such intercourse is, and ever must be, gain, or the hopes of gain; as neither the public, nor the individual, would intentionally pursue any unprofitable intercourse or commerce.

3. Gain being the principle of trade, the whole mystery of trade must therefore consist in prosecuting methods whereby gain or advantage may be obtained.

In transactions of trade, it is not to be supposed that, like gaming, what one party gains the other must necessarily lose. The gain to each may be equal. If A has more corn than he can consume, but wants cattle, and B has more cattle, but wants

corn, an exchange is gain to each; hereby the common stock of comforts in life is increased.

4. Freedom and protection are most indisputable principles whereon the success of trade must depend, as clearly as an open good road tends towards a safe and speedy intercourse; nor is there a greater enemy to trade than constraint.

5. Governments which have adopted those plain simple principles have been greatly benefited.

6. Were princes, in general, to abolish all sorts of prohibitory laws, trade in general would florish most in those countries where the happy situation, the mildness of the climate, the activity and industry of the inhabitants, would furnish means for a speedy and useful intercourse, reciprocally to supply any real or ideal want.

When princes make war by prohibiting commerce, each may hurt himself as much as his enemy. Traders, who by their business are promoting the common good of mankind, as well as farmers and fishermen, who labor for the subsistence of all, should never be interrupted or molested in their business, but enjoy the protection of all in the time of war as well as in time of peace.

This policy, those we are pleased to call barbarians, have, in a great measure, adopted; for the trading subjects of any power, with whom the emperor of Morocco may be at war, are not liable

to capture, when within sight of his land, going or coming, and have otherwise free liberty to trade and reside in his dominions.

As a maritime power, we presume it is not thought right that Great Britain should grant such freedom, except partially; as in the case of war with France, when tobacco is allowed to be sent thither under the sanction of passports.

7. We are no more to expect this, than that the whole world should be governed by the same laws. In our opinion, however, no laws which the art of man can devise, will or can hinder, or entirely stop the current of, a profitable trade; any more than the severest laws could prevent the satisfying of hunger, when any chance or opportunity offered to gratify it.

8. Nevertheless, so far as it is possible, according to the different modes and constitutions of each state, freedom and protection should be ever had in view by its respective government.

9. For whatever law is enacted, abridging a freedom or liberty, which the true interest of the state demands, or which does not grant protection where it may be wanted, must clearly be detrimental.

10. We are well aware, that in many cases, individuals may endeavor at an intercourse or trade, whereby the public, in one particular point, may seem injured; and yet it may be out of the power of the state to hinder it, without breaking in upon

the freedom of trade; so that the Dutchman who, when Antwerp was besieged, furnished arms, ammunition, and provision to the Spaniards, and gloried in it, though a chief magistrate of Amsterdam, was not so very wrong in his principles in general, as at first sight might appear: for this Dutchman ran the risk of losing his ammunition, &c. which, if taken, would have been indeed his loss, but a gain to the captors his countrymen; and if sold, and delivered to the enemy, brought profit to him, and in consequence to the state of which he was a member. This man, to evince how much he held freedom in trade to be essential, used a very strong figure; when owning his having furnished the enemy of the state with ammunition, &c. he added; that he would, to prosecute his trade, sail through hell, at the risk of singeing his sails.

It is generally a vain imagination, that if we do not furnish an enemy with what he wants, he cannot be supplied elsewhere. Since we are to suffer the mischief he may do with it, why should we not receive the profit that arises on supplying it? Thus might the Dutchman have reasoned when he supplied the enemy with ammunition, &c.

11. We have, as a first principle, laid down what we apprehend every one must allow, that gain, or the hopes of gain, is the mover of all intercourse or trade. Herein, as above hinted, must be comprehended, all matters of use, in the first

instance: and then, matters of ambition, delight, opinion: in one word, luxury.

12. Now things of real use can only be meat, drink, clothing, fuel, and habitation. The several particulars relative to these, every one's mind can suggest: to enumerate would almost be endless.

13. As to meat, in a country where corn, fruits, and cattle can be raised, and bred; the inhabitants must be wanting in industry, to cultivate the lands, or they cannot, in the common course of things, want help from their neighbors, for sustenance.

The same as to drink; if for it they will content themselves with the beverage made of their own corn and fruits.

And so of clothing; if they can be satisfied to be clad with the manufactures made from the produce of their own country.

As to fuel and habitation, there are very few countries which do not afford these articles.

14. The real want of all or any of these necessaries, must, and ever will be, an incentive to labor; either by every individual himself, in the community, or by those, to whom an equivalent is given for their labor.

15. When ambition, delight, opinion, otherwise luxury, come to be considered, the field is extremely enlarged; and it will require a copious deliberation and ascertainment.

16. For luxury may be carried to such a height,

as to be thought by some to be prejudicial to the state; though we, in a general sense, cannot well apprehend it can: inasmuch as what we call riches, must be the cause of luxury, taken in all its branches.

17. Now riches, as we conceive them, consist in whatever either a state or an individual have, more than is necessary, to procure the above essentials, which are only of real use, viz. meat and drink, and clothes, fire and shelter.

This more or abundance, from whatsoever cause it may proceed, after the bartering for, and procuring those essentials, would absolutely, and to all intents, be useless, and of no manner of avail, were it not that delight, and opinion, came in aid, to cause what we will call ideal wants; which wants, our passions, put into our make by the almighty hand that formed us, cause us to be almost as solicitous to provide for, and to supply, as if such wants were real.

18. We therefore must repeat, that from motives to acquire what may be thought of real or ideal use, spring the intercourse or trade between nations, as well as between individuals: and it seems to be self-evident that the produce of the land, and of industry in general, must supply all our wants: and consequently our trade.

19. Now, though it is hardly to be expected, as above hinted, that princes should allow of a general free trade or intercourse, because they seldom

know their own true interest; yet it does not follow that fundamental maxims should not be attended to in governing an industrious people. Some of these principles we beg leave to expatiate on.

20. Land, to bring forth its increase, must be cultivated by man and beast. It is therefore the duty and interest of the state to rear both man and beast; and in their respective classes to nourish and cherish them.

21. Industry in all shapes, in all instances, and by all means, should be encouraged and protected: indolence by every possible method rooted out.

All that live must be subsisted. Subsistence costs something. He that is industrious produces by his industry, something that is an equivalent, and pays for his subsistence. He is therefore no charge or burden to society. The indolent are an expense, uncompensated.

There can be no doubt but all kinds of employment that can be followed without prejudice from interruptions; work that can be taken up, and laid down, often in a day, without damage; such as spinning, knitting, weaving, &c. are highly advantageous to a country: because, in them, may be collected all the produce of those fragments of time that occur in family business, between the constant and necessary parts of it, that usually occupy females; as the time between rising and preparing breakfast; between breakfast and preparing for dinner, &c. The amount of all these

fragments is, in the course of a year, very considerable to a single family; to a state proportionably. Highly profitable therefore it is, in this case also, to follow that divine direction, gather up the fragments, that nothing be lost. Lost time is lost subsistence; it is therefore lost treasure.

Hereby, in several families, many yards of linen have been produced from the employment of these fragments only, in one year, though such families were just the same in number as when not so employed.

It was an excellent saying of a certain Chinese emperor, "I will, if possible, have no idleness in my dominions; for if there be one man idle, some other man must suffer cold and hunger." We take this emperor's meaning to be, that the labor due to the public, by each individual, not being performed by the indolent, must naturally fall to the share of others, who must thereby suffer.

22. Whatever can contribute towards procuring from the land, and by industry, a produce wherewith other nations may be supplied, ought highly to be encouraged.

23. Materials wanting in a country to employ its inhabitants, ought by all means to be procured. Gold and silver, those tokens of riches, used as such, and otherwise of little use, are not near so estimable. The bartering of them for such materials is manifestly advantageous.

24. These, as we apprehend, are incontrovertible

principles, on which a wise government will found its resolutions.

25. That the use of the produce of other countries for ideal wants ought to be discouraged, particularly when the produce of the land, or of industry, are not given in exchange for them, has been strongly urged by many. On the grand principle of freedom in trade, we cannot well admit it: for it is plain the luxurious will use, and the trader, to prosecute his gain, will procure, such foreign produce: nor do prohibitory laws, or heavy duties, hinder. Nevertheless, to allow for a moment the doctrine, we will remark, that only the establishing it as a mode or fashion amongst the opulent and great, can possibly effectuate a disuse or discouragement.

In fact, the produce of other countries can hardly be obtained, unless by fraud or rapine, without giving the produce of our land or our industry in exchange for them. If we have mines of gold and silver, gold and silver may then be called the produce of our land. If we have not, we can only fairly obtain those metals by giving for them the produce of our land or industry. When we have them, they are then only that produce or industry in another shape; which we may give, if the trade requires it, and our other produce will not suit, in exchange for the produce of some other country that furnishes what we have more occasion for, or more desire. When we have, to an incon-

venient degree, parted with our gold and silver, our industry is stimulated afresh to procure more; that by its means we may contrive to procure the same advantage.

In this place it will be proper to observe upon an erroneous doctrine, which has been often strenuously insisted on, that the cheapness of provisions must render manufactures cheap; and that plenty of money conduces to the benefit of trade. We shall endeavor to prove that industry alone does both.

26. Providence has wisely ordained that there should be different occupations and pursuits amongst men, and that the rich and poor should be actuated by different wants, whether real or ideal. It is next to impossible that the rich should be without desires, or wishes for greater acquisitions; or the poor without being necessitated to acquire what must supply their real wants. If the rich curtail their desires, or wishes, their riches serve, in proportion to their not using them, no more than ore in an unworked mine. If the poor man, by *one* day's labor can supply his real wants for *two* days, and sits idle the half of his time, he may be considered in such idle time as a monk or a cripple with regard to the community. If a thirst for acquisition move the rich man, he industriously employs all his riches. If the scarcity of provisions compel the poor man to work his whole time, he assuredly, by his industry, must make more

manufactures than only working half of it. Hence we conclude, that gain is the first mover; and industry, and the desire of supplying our wants, the intermediate movers of all intercourse or trade. We however must observe, that a government truly wise should always, as far as the general good allows, be as solicitous to procure plenty of provisions, whereby both man and beast may be kept in good health and strength, as to encourage industry. For industry cannot be sufficiently sustained without the strength arising from plenty of provisions.

The common people do not work for pleasure generally, but from necessity. Cheapness of provisions makes them more idle; less work is then done; it is then more in demand proportionally; and of course the price rises. Dearness of provisions obliges the manufacturer to work more days and more hours: thus more work is done than equals the usual demand; of course it becomes cheaper, and the manufactures in consequence.[1]

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[1] These maxims and many others in this tract, are to be considered as applicable to European society, particularly to England. where industry is not applied to the profit of the individual who labors; but where one or a few individuals, with large capitals, make a monopoly of the industry of thousands. These thousands barely subsisted by labor, and from the scantiness of their reward or wages, never able to reserve a surplus to accumulate for their children or for old age, are ever dependent on their employers; and where labor is the only occupation, and bare existence the only hope, there idleness is an enjoyment.

27. As to plenty of money being a benefit to trade and manufactures, we apprehend every one conversant therein must know that the coin, by which we generally understand money, of every respective state, is by no means the mover of the intercourse or tradings of the world in general. Gold and silver in bullion, or in an uncoined mass, are rather more so; being, in point of value, a merchandise less liable to variation than any other. It is true that coin may be liable, in the fluctuation of trade, to be made a merchandise of; but as by constant use, the pieces of coin become lighter than their original weight, they thereby are less fit for merchandise. We therefore may say, that coins, in general, can no otherwise be useful, than as the common measure between man and man, as serving to barter against, or exchange for, all kinds of commodities. Certain it is that coins cannot be ranked amongst those things which are *only of real use.* Let us therefore suppose pieces of coin to be counters; and to simplify the matter still more, suppose every manufacturer to have of these counters any sum whatever, will it follow, that any sort of manufacture shall be industriously attended to, or more work done than when no more counters than just enough to barter for the real wants of meat, drink, and clothes, &c. can be procured by labor? Surely no. It must be the desire of supplying our wants, which excites industry as above

hinted, that alone sets that trade going, and only can procure plenty of manufactures.

28. It is, nevertheless, the duty of government to stamp coins [illegible] counters of different sorts and denominations, so that time, of all things the most precious, be not wasted in settling the respective exchangings amongst mankind. Nevertheless the plenty or scarcity of those coins cannot entirely depend on any government, but on the general circulation and fluctuation of trade, which may make them a merchandise, without the least detriment; as it must be allowed, that the precious metals gold and silver, of which such coins are principally composed, are no other than merchandise acquired from countries where there are mines, by those countries which have none, in exchange for the produce of their land, or of their manufactures.

29. That the welfare of any state depends on its keeping *all* its gold and silver, either in bullion or in coin, must be founded on a very narrow principle indeed. All republics we know of, wisely think otherwise. Spain, the grand source of silver, has of late years, very justly, allowed the free exportation of it, paying a duty, as in Great Britain lead and tin do: nor prior to this permission could their penal laws in Spain hinder its being exported; for it was a commodity which that kingdom was under a necessity of giving as an equivalent for what was furnished to them by other countries.

Could Spain and Portugal have succeeded in executing their foolish laws for "*hedging in the cuckoo*," as Locke calls it, and have kept at home all their gold and silver, those metals would, by this time, have been of little more value than so much lead or iron. Their plenty would have lessened their value. We see the folly of these edicts; but are not our own prohibitory and restrictive laws, that are professedly made with intention to bring a balance in our favor from our trade with foreign nations to be paid in money, and laws to prevent the necessity of exporting that money, which, if they could be thoroughly executed, would make money as plenty, and of as little value; I say, are not such laws akin to those Spanish edicts; follies of the same family?

30. In Great Britain, the silver coin bearing a disproportion to gold more than in neighboring states, of about five in the hundred, must, by that disproportion, become merchandise, as well for exportation, as for the manufactures at home, in which silver is employed, more than if it remained in the mass uncoined. This might be remedied without injuring the public, or touching the present standard, which never should be done, only by enacting that sixty-five shillings should be cut out of one pound weight of standard silver, instead of sixty-two, which are the number now ordained by law. We must however remark, that, whenever by any extraordinary demand for silver, a pound

weight, bought even for sixty-five shillings, can be sent abroad to advantage, or melted down for manufactures, no prohibitory laws will hinder its exportation or melting, and still becoming a merchandise.

31. Coiners have pointed out, though at the risk of the gallows, a measure which we think would be advisable in some degree for government to adopt. They coin and circulate shillings of such weight as to gain ten to fourteen in the hundred, and upwards: as out of a pound of standard silver they cut sixty-eight or seventy-one shillings. That these light shillings or counters are useful, though the public be so greatly imposed on, is evident. It must be presumed, that every thing is put in practice by government to detect and stop this manifest roguery. If so, can it on the one hand be supposed the public purse should bear the burden of this fraud? yet, on the other hand, having no supply of legal shillings or counters, the utility of the illegal ones forces them, as it were, on the public. The power of the legislature to correct the erroneous proportion of five in the hundred, as above mentioned, is indubitable; but whether every private person possessed of these counters, or the public purse, should be obliged to bear the loss on a re-coinage, seems a difficult point to determine; as it may be alleged, that every private person has it in his power to accept, or refuse any coin, under the weight, as by law

enacted, for each denomination. If the former, he does it to his own wrong, and must take the consequences. The individual, on the other hand, has to allege the almost total want of lawful counters; together with the impossibility or neglect of hindering those of an inferior weight from being suffered to be current. It may be submitted, that as the use of coin is for public utility, any loss which arises in the coin either by wearing, or even by filing and sweating, ought to be made good by calling in the coin after a certain number of years from the time of coinage, and receiving the money called in at the charge of the public. We are well aware what latitude such a resolution might give to the coiners of shillings, the filers, and the sweaters of gold; but taking proper measures beforehand, this evil might, we think, in a great degree be prevented.

32. In the beginning of his present majesty's reign, quarter guineas were wisely ordered to be coined; whereby the want of silver coin was in some degree supplied: which would still be more so, were thirds and two-thirds of guineas to be coined. We cannot conceive why this is not done; except that these denominations are not specified in his majesty's indenture with the master of the mint; which in our humble opinion ought to be rectified.

33. We think it not improper here to observe, that it matters not, whether silver or gold be called

the standard money; but it seems most rational that the most scarce and precious metal should be the unit or standard.

That as to copper, it is fit for money, or a counter, as gold or silver, provided it be coined of a proper weight and fineness: and just so much will be useful as will serve to make up small parts in exchange between man and man, and no more ought to be coined.

As to paper circulating as money, it is highly profitable, as its quick passing from one to another is a gain of time, and thereby may be understood to add hands to the community: inasmuch as those, who would be employed in telling and weighing, will follow other business. The issuers or coiners of paper are understood to have an equivalent to answer what it is issued for, or valued at; nor can any metal or coin do more than find its value.

§ It is impossible for government to circumscribe, or fix the extent of paper credit, which must, of course, fluctuate. Government may as well pretend to lay down rules for the operations, or the confidence, of every individual, in the course of his trade. Any seeming temporary evil arising, must naturally work its own cure.

34. As some principles relative to exchange have in our opinion been treated of in a very confused manner, and some maxims have been held out upon that subject, which tend only to mislead, we

shall here briefly lay down what, according to our opinion, are self-evident principles.

35. Exchange, by bills, between one country or city and another, we conceive to be this. One person wants to get a sum from any country or city; consequently has his bill or draft to sell: another wants to send a sum thither; and therefore agrees to buy such bill or draft. He has it at an agreed-for price, which is the course of the exchange. It is with this price for bills as with merchandise; when there is a scarcity of bills in the market, they are dear; when plenty, they are cheap.

36. We judge it needless to enter into the several courses and denominations of exchanges which custom hath established: they are taught at school. But we think we must offer a few words, to destroy an erroneous principle that has misled some, and confused others; which is, that by authority, a certain par, or fixed price of exchange, should be settled between each respective country; thereby rendering the currency of exchange as fixed as the standard of coin.

37. We have above hinted, that plenty and scarcity must govern the course of exchange: which principle, duly considered, would suffice on the subject; but we will add, that no human foresight can absolutely judge of the almost numberless fluctuations in trade; which vary, sometimes directly, sometimes indirectly, between countries:

consequently no state or potentate can, by authority, any more pretend to settle the currency of the prices of the several sorts of merchandise sent to and from their respective dominions, than they can a par of exchange. In point of merchandise, indeed, where there is a monopoly of particular commodities, an exception must be allowed, as to such articles; but this is not at all applicable to trade in general; for the encouragement of which we cannot too often repeat, that *freedom and security are most essentially necessary.*

38. Another specious doctrine, much labored by theorists, in consequence of that relating to the par, is, that the exchange between any particular country being above or below par, always shows whether the reciprocal trade be advantageous or disadvantageous. It is, and must be allowed, that in trade nothing is given without adequate returns or compensations; but these are so various and so fluctuating between countries, as often indirectly as directly, that there is no possibility of fixing a point from whence to argue; so that should there happen a greater variation than of two or three more in the hundred, at any certain period in the exchange, above or below what is called the par or equality of the money of one country to that of another, influenced by the fluctuations and circulations in trade, it does not follow, that a trade is advantageous or disadvantageous, excepting momentarily, if one may so say,

which can be of no consequence to the public in general, as the trade from advantageous may become disadvantageous, and *vice versa*; and, consequently, the deducing of reasons from what in its nature must be fluctuating, can only help to embarrass, if not mislead.

39. To return to trade in general. Our principles, we apprehend, may hold good for all nations, and ought to be attended to by the legislative power of every nation. We will not discuss every particular point: nor is it to our purpose to examine the pretended principles or utility whereon monopolies are generally established. That the wisdom of government should weigh and nicely consider any proposed regulation on those principles, we humbly judge to be self-evident; whereby may be seen whether it coincides with the general good. Solomon adviseth *not to counsel with a merchant for gain.* This, we presume, relates to the merchant's own particular profit; which, we repeat, must ever be the spring of his actions. Government ought, notwithstanding, to endeavor to procure particular informations from every one; not only from those actually employed, or those who have been concerned in particular branches of trade, but even from persons who may have considered of it theoretically and speculatively.

Perhaps, in general, it would be better if government meddled no farther with trade than to protect it, and let it take its course. Most of the

statutes, or acts, edicts, arrets, and placarts of parliaments, princes, and states, for regulating, directing, or restraining of trade, have, we think, been either political blunders, or jobs obtained by artful men for private advantage, under pretence of public good. When Colbert assembled some wise old merchants of France, and desired their advice and opinion, how he could best serve and promote commerce, their answer, after consultation, was, in three words only, *Laissez nous faire:* Let us alone. It is said, by a very solid writer of the same nation, that he is well advanced in the science of politics who knows the full force of that maxim—*Pas trop gouverner:* Not to govern too much. Which, perhaps, would be of more use when applied to trade, than in any other public concern. It were therefore to be wished, that commerce was as free between all the nations of the world, as it is between the several counties of England: so would all, by mutual communication, obtain more enjoyments. Those counties do not ruin one another by trade; neither would the nations. No nation was ever ruined by trade; even seemingly the most disadvantageous.

Wherever desirable superfluities are imported, industry is excited; and therefore plenty is produced. Were only necessaries permitted to be purchased, men would work no more than was necessary for that purpose.

40. Though we waive a discussion on particular

branches of trade, as the field is too large for our present purpose; and that particular laws and regulations may require variation, as the different intercourses, and even interests of states, by different fluctuations, may alter; yet, as what relates to bounties or premiums, which the legislature of Great Britain has thought fit to grant, hath been by some deemed, if not ill-judged, unnecessary; we hope our time not ill bestowed, to consider of the fitness and rectitude of the principle on which we apprehend these bounties or premiums have been granted.

41. It must, we think, on all hands be allowed, that the principle whereon they are founded must be an encouragement tending to a general benefit, though granted on commodities, manufactures, or fisheries, carried on in particular places and countries, which are presumed or found to require aid from the public purse for farther improvement.

Of the bounties, some having had the proposed effect, are discontinued: others are continued, for the very reason they were first given.

In our opinion, no doubt can arise as to the utility of these grants from the public purse to individuals. The grand principle of trade, which is gain, is the foundation of bounties: for, as every individual makes a part of the whole public, consequently, whatever benefits the individual must benefit the public: hereby the wisdom of the legislature is most evident; nor should it in any

wise be arraigned, though ill success attended any particular commodity, manufacture, or fishery, for the encouragement of which bounties have been established.

We are well aware that it is not impossible the purpose of bounty may have been perverted, with a view to improper gain; but it is the duty of the legislature to use the proper measures for preventing such iniquity. This abuse, however, cannot be adduced as an argument against the benefit arising from allowing bounties.

42. These principles in regard to bounties or premiums, are applicable to most articles of commerce, except wheat and other grain, which we shall consider and enlarge on, as being of a complicated nature, and concerning which mankind have, at particular times, been divided in opinion.

43. It seems to us, that this bounty on grain was intended, not only to encourage the cultivating of land for the raising of it in abundance in this kingdom, for the use of its inhabitants, but also to furnish our neighbors, whenever the kind hand of Providence should be pleased to grant a superfluity.

44. It never can be presumed that the encouragement by the bounty insures to the community an uninterrupted constant plenty; yet, when the grower of grain knows he may, by such bounty, have a chance of a foreign market for any excess he may have, more than the usual home consump-

tion, he the more willingly labors and improves his land, upon the presumption of having a vent for his superfluity, by a demand in foreign countries; so that he will not probably be distressed by abundance; which, strange as it may seem to some, might be the case by his want of sale, and his great charges of gathering in his crop.

45. As there are no public granaries in this kingdom, the legislature could devise no better means than to fix stated prices under which the bounty or encouragement from the public purse should be allowed. Whenever the current prices exceeded those stipulated, then such bounty should cease.

46. Few consider, or are affected, but by what is present. They see grain, by reason of scanty crops, dear; therefore all the doors for gain, to the cultivators of it, must always be kept shut. The common outcry is, that the exporting our wheat furnishes bread to our neighbors cheaper than it can be afforded to our poor at home; which affects our manufacturers, as they can thereby work cheaper. To this last allegation we must refer to what we have said, section 26; though the former, that wheat is, by the bounty, afforded to our neighbors cheaper than to us at home, must in general be without foundation, from the several items of charge attending the exportation of grain, such as carriage, factorage, commission, porterage, &c. The freight paid to our own shipping, to which

alone the bounty is restrained, must, when duly considered, very sufficiently counterbalance the bounty; so that more than what is given out of the public purse is put into the pockets of individuals for the carriage, &c.: therefore we think we may well presume that, in general, grain exported comes dearer to the foreigner than to the consumer in Great Britain.

47. Nothing can be more evident, we apprehend, than that the superfluity of our grain being exported, is a clear profit to the kingdom, as much as any other produce of our labor, in manufactures, in tin, or any commodities whatsoever.

48. It behoves us, however, indubitably, to have an eye towards having a sufficiency of grain for food in this country, as we have laid down, section 26: and were the legislature to enact, that the justices of the peace, at the Christmas quarter session, should have power to summon all growers of grain, or dealers therein, and upon oath to examine them as to the quantity then remaining; returns of which quantities should be made to the lords of the treasury, to be laid before parliament; the legislature would, upon such returns, be able to judge whether it would be necessary to enable his majesty, with the advice of his council, to put a stop to any farther exportation at such times as might be thought proper.

49. Or, it is submitted, whether the legislature would not act more consistent with the principle

of granting bounties, by repealing the act allowing the present bounty on the several sorts of grain at the now fixed prices, and reduce these prices as follow :—

On wheat from forty-eight to thirty-six or thirty-two shillings.

On barley from twenty-four to eighteen or sixteen a quarter; and so in proportion for any other grain. In short, diminish the present standard prices, under which the bounty is granted, one quarter or one third.

50. In our humble opinion, this last method would be by much the most simple and eligible, as consistent with our grand principle of freedom in trade, which would be cramped if dependent annually on parliamentary deliberation.

51. The advocates for not lowering the present stipulated prices that command the bounties from the public purse may allege, that our ancestors deemed them necessary, on the principle of granting any bounty at all, which we have above hinted, section 43. We do not controvert the wisdom of the principle for granting a bounty; for it must have been, and ever will be, an encouragement to cultivation; and consequently it would be highly improper wholly to discontinue it; nevertheless, if it has answered one great end proposed, which was cultivation and improvement, and that it is incontrovertible the cultivator has, by the improve-

ments made by the encouragement of the bounty, a living profit at the reduced prices of thirty-two or thirty-six shillings, sixteen or eighteen, &c. as above, which probably, when our ancestors enacted the law for granting the bounty, they understood the cultivators could not have; it seems clear, that there ought to be the proposed change and reduction of the bounty prices, as above mentioned.

52. The French, intent on trade, have a few years since rectified a very gross mistake they labored under, in regard to their commerce in grain. One county or province in France should abound, and the neighboring one, though almost starving, should not be permitted to get grain from the plentiful province, without particular license from court, which cost no small trouble and expense. In sea-port towns wheat should be imported; and soon after, without leave of the magistrates, the owner should only have liberty to export one quarter or one third of it. They are now wiser; and through all the kingdom the corn trade is quite free: and what is more, all sorts of grain may be exported upon French bottoms only, for their encouragement; copying, we presume our law, whenever the market prices for three following days shall not exceed above forty-five shillings sterling for a quarter of wheat: our reason for mentioning this is only to show that other nations

are changing their destructive measures, and that it behoves us to be careful that we pay the greatest attention to our essential interests.

In inland high countries, remote from the sea, and whose rivers are small, running from the country, not to it, as is the case of Switzerland, great distress may arise from a course of bad harvests, if public granaries are not provided, and kept well stored. Anciently, too, before navigation was so general, ships so plenty, and commercial connexions so well established, even maritime countries might be occasionally distressed by bad crops. But such is now the facility of communication between those countries, that an unrestrained commerce can scarce ever fail of procuring a sufficiency for any of them. If, indeed, any government is so imprudent as to lay its hands on imported corn, forbid its exportation, or compel its sale at limited prices, there the people may suffer some famine from merchants avoiding their ports. But wherever commerce is known to be always free, and the merchant absolute master of his commodity, as in Holland, there will always be a reasonable supply.

When an exportation of corn takes place, occasioned by a higher price in some foreign country, it is common to raise a clamor, on the supposition that we shall thereby produce a domestic famine. Then follows a prohibition, founded on the

imaginary distress of the poor. The poor, to be sure, if in distress, should be relieved; but if the farmer could have a high price, for his corn, from the foreign demand, must he, by a prohibition of exportation, be compelled to take a low price, not of the poor only, but of every one that eats bread, even the richest? The duty of relieving the poor is incumbent on the rich; but, by this operation, the whole burden of it is laid on the farmer, who is to relieve the rich at the same time. Of the poor, too, those who are maintained by the parishes have no right to claim this sacrifice of the farmer; as, while they have their allowance, it makes no difference to them whether bread be cheap or dear. Those working poor who now mind business five or four days in the week, if bread should be so dear as to oblige them to work the whole six, required by the commandment, do not seem to be aggrieved so as to have a right to public redress. There will then remain, comparatively, only a few families in every district; who, from sickness or a great number of children, will be so distressed by a high price of corn, as to need relief; and these should be taken care of, by particular benefactions, without restraining the farmer's profit.

Those who fear that exportation may so far drain the country of corn, as to starve ourselves, fear what never did nor ever can happen. They may as well when they view the tide ebbing to-

wards the sea, fear that all the water will leave the river. The price of corn, like water, will find its own level. The more we export, the dearer it becomes at home. The more is received abroad, the cheaper it becomes there; and as soon as these prices are equal, the exportation stops of course. As the seasons vary in different countries, the calamity of a bad harvest is never universal. If then all ports were always open, and all commerce free, every maritime country would generally eat bread at the medium price, or average of all the different harvests; which would probably be more equal than we can make it by our artificial regulations, and therefore a more steady encouragement to agriculture. The nations would all have bread at this middle price; and that nation which at any time inhumanly refuses to relieve the distresses of another nation, deserves no compassion when in distress itself.

We shall here end these reflections, with our most ardent wishes for the prosperity of our country, and our hopes that the doctrine we have endeavored to inculcate as to the necessity of protection and freedom, in order to insure success in trade, will be ever attended to by the legislature in forming their resolutions relating to the commerce of these kingdoms.

PREFACE TO THE APPENDIX.[1]

The clamor made of the great inconveniencies suffered by the community in regard to the coin of this kingdom, prompted me in the beginning of his majesty's reign to give the public some reflections on coin in general; on gold and silver as merchandise; and I added my thoughts on paper passing as money.

As I trust the principles then laid down are founded in truth, and will serve now as well as then, though made fourteen years ago, to change any calculation would be of little use.

Some sections in the foregoing essay of principles of trade, which might in this appendix appear like a repetition, have been omitted.

I always resolved not to enter into any particular deduction from laws relating to coin; or into any minutiæ, as to accurate nicety in weights. My intention was, and still is, no more than to endeavor to show, as briefly as possible, that what relates to coin, is not of such a complex, abstruse nature as it is generally made; and that no more than common justice with common sense are required in all regulations concerning it.

Perhaps more weighty concerns may have pre-

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[1] This preface was written entirely by Mr. Whately; but is too valuable to be separated from the tract to which it is attached.

vented government doing more in regard to coin, than ordering quarter guineas to be made; which till this reign had not been done.

But as I now judge by the late act relating to gold coin, that the legislature is roused, possibly they may consider still more of that, as well as of silver coin.

Should these reflections prove of any public utility, my end will be answered.

REFLECTIONS ON COIN IN GENERAL.

1. Coins are pieces of metal, on which an impression is struck; which impression is understood by the legislature to ascertain the weight and the intrinsic value, or worth of each piece.

2. The real value of coins depends not on a piece being called a guinea, a crown, or a shilling; but the true worth of any particular piece of gold or silver, is what such piece contains of fine or pure gold or silver.

3. Silver and copper being mixed with gold, and copper with silver, are generally understood to render those metals more durable when circulating in coins; yet air and moisture evidently affect copper, whether by itself or mixed with other metal; whereas pure gold or silver are much less affected or corroded thereby.

4. The quantity of silver and copper so mixed by way of alloy, is fixed by the legislature. When melted with pure metal, or added or extracted to

make a lawful proportion, both gold and silver are brought to what is called standard. This alloy of silver and copper is never reckoned of any value. The standard once fixed, should ever be invariable; since any alteration would be followed by great confusion and detriment to the state.

5. It is for public convenience, and for facilitating the bartering between mankind for their respective wants, that coins were invented and made; for were there no coins, gold and silver might be made, or left pure; and what we now call a guinea's worth of any thing, might be cut off from gold, and a crown's worth from silver, and might serve, though not so commodiously as coin.

6. Hence it is evident that in whatever shape, form, or quality, these metals are, they are brought to be the most common measure between man and man, as serving to barter against or exchange for all kinds of commodities; and consequently are no more than an universal-accepted merchandise; for gold and silver in bullion, that is to say, in an uncoined mass, and gold or silver in coin, being of equal weight, purity, and fineness, must be of equal value, the one to the other; for the stamp on either of these metals, duly proportioned, neither adds to, nor takes from their intrinsic value.[1]

[1] There is an incidental value, which arises from the authority of the state, which is in the nature of a credit or assurance of value given by the state, that either issues or authorises the issue of the coin.

7. The prices of gold and silver as merchandise, must in all countries, like other commodities, fluctuate and vary according to the demand; and no detriment can arise therefrom, more than from the rise and fall of any other merchandise. But if, when coined, a due proportion of these metals the one to the other, be not established, the disproportion will be felt and proved; and that metal wherein the excess in the proportion is allowed, will preferably be made use of, either in exportation or in manufacture; as is the case now, in this kingdom, in regard to silver coin, and which in some measure is the occasion of its scarcity.

For so long as 15 ounces and about one-fifth of pure silver in Great Britain are ordained and deemed to be equal to one ounce of pure gold, whilst in neighboring states, as France and Holland, the proportion is fixed only 14 and a half ounces of pure silver, to one ounce of pure gold, it is very evident that our silver, when coined, will always be the most acceptable merchandise, by near five in the hundred, and consequently more liable to be taken away or melted down, than before it received the impression at the mint.

8. Sixty-two shillings only are ordained by law to be coined from 12 ounces of standard silver; now, following the proportion above mentioned, of $15\frac{1}{5}$ to $14\frac{1}{2}$, no regard being necessary as to alloy, 65 shillings should be the quantity cut out of those 12 ounces.

9. No everlasting invariable fixation for coining can be made from a medium of the market price of gold and silver, though that medium might with ease be ascertained so as to hinder either coined gold or silver from becoming a merchandise; for whenever the price shall rise above that medium, so as to give a profit, whatever is coined will be made a merchandise. This in the nature of things, must come from the general exchangings, circulation, and fluctuation in trade, and cannot be hindered; but assuredly the false proportions may be amended by the legislature, and settled as the proportion between gold and silver is in other nations; so as not to make, as now is the case, our coined silver a merchandise, so much to be preferred to the same silver uncoined.

10. What has been said seems to be self-evident; but the following calculations made on the present current price of silver and gold, may serve to prove beyond all doubt, that the proportion now fixed between gold and silver should be altered and fixed as in other countries.

By law, 62 shillings are to be coined out of one pound, or 12 ounces of standard silver. This is 62 pence an ounce. Melt these 62 shillings, and in a bar, this pound weight at market will fetch 68 pence an ounce, or 68 shillings the pound. The difference therefore between coined and uncoined silver in Great Britain is now nine and two-thirds per cent.

Out of a pound or 12 ounces of standard gold, 44 guineas and a half are ordained to be coined. This is 3*l.* 17*s.* 10½*d.* an ounce. Now the current market price of standard gold is 3*l.* 19*s.* an ounce, which makes not quite 1½ per cent. difference between the coined and uncoined gold.

The state, out of duties imposed, pays for the charge of coining, as indeed it ought; for it is for public convenience, as already said, that coins are made. It is the current market price of gold and silver that must govern the carrying it to the mint. It is absurd to think any one should send gold to be coined that should cost more than 3*l.* 17*s.* 10½*d.* an ounce, or silver more than 62 pence the ounce; and as absurd would it be to pretend, that those prices *only* shall be the constant invariable prices. It is contended that there is not a proper proportion fixed in the value of one metal to another, and this requires alteration.

11. It may be urged, that should the legislature fix the proportion of silver to gold as in other countries, by ordering 65 shillings instead of 62 to be cut out of a pound of standard silver, yet still there would be 4⅔ per cent. difference between coined and uncoined silver; whereas there is but about 1½ per cent. difference in gold.

On this we shall observe that the course of trade, not to mention extraordinary accidents, will make one metal more in request at one time than another; and the legislature in no one particular

country, can bias or prescribe rules or laws to influence such demand; which ever must depend on the great chain of things, in which all the operations of this world are linked. Freedom and security only are wanted in trade; nor does coin require more, if a just proportion in the metals be settled.

12. To return to gold: it is matter of surprise, that the division of the piece called a guinea, has not been made smaller than just one half as it now is; that is, into quarters, thirds, and two-thirds. Hereby the want of silver coin might be greatly provided for; and those pieces, together with the light silver coin, which can *only now* remain with us, would sufficiently serve the uses in circulation.

In Portugal, where almost all their coin is gold, there are divisions of the moedas, or 27 shilling pieces, into tenths, sixths, quarters, thirds, halves, and two-thirds. Of the moeda and one-third, or 36 shilling piece, into eighths, quarters, and halves.

13. That to the lightness of the silver coin now remaining in Great Britain we owe all the silver coin we now have, any person with weights and scales may prove; as upwards of 70 shillings coined in the reign of king William, or dexterously counterfeited by false coiners, will scarce weigh 12 ounces, or a pound troy.

14. All the art of man can never hinder a con-

stant exportation and importation of gold and silver, to make up for the different calls and balances that may happen in trade; for were silver to be coined as above, 65 shillings out of a pound troy weight of standard silver; if those 65 shillings would sell at a price that makes it worth while to melt or export them, they must and will be considered and used as a merchandise; and the same will hold as to gold.

Though the proportion of about 14½ of pure silver to one of pure gold, in neighboring states be *now* fixed, in regard to their coin, and it is submitted such proportion should be attended to in this kingdom, yet that proportion may be subject to alteration; for this plain reason, that should the silver mines produce a quantity of that metal so as to make it greatly abound more in proportion than it now does, and the gold mines produce no more than now they do, more silver must be requisite to purchase gold.

15. That the welfare of any state depends on its keeping *all* its gold and silver, either in bullion or in coin, is a very narrow principle; all the republics we know of, wisely think otherwise. It is an utter impossibility; nor should it ever be aimed at; for gold and silver are as clearly a merchandise as lead and tin; and consequently should have a perfect freedom and liberty,[1] coined

[1] As a general principle this is unquestionably true; but it must be general, or every nation with whom commerce is ex-

and uncoined, to go and to come, pass and repass, from one country to another, in the general circulation and fluctuation of commerce, which will ever carry a general balance with it: for we should as soon give our lead, our tin, or any other product of our land or industry, to those who want them, without an equivalent in some shape or other, as we should gold or silver; which it would be absurd to imagine can ever be done by our nation, or by any nation upon earth.

16. From Spain and Portugal come the greatest part of gold and silver: and the Spanish court very wisely permits the exportation of it on paying a duty, as in Great Britain lead and tin do, when exported; whereas heretofore, and as it still continues in Portugal, penal laws were enacted against the sending it out of the country. Surely princes by enacting such laws, could not think they had it in their power to decree and establish, that their subjects, or themselves, should not give an equivalent for what was furnished to them!

17. It is not our intention to descend into, or to discuss minutely, particular notions or systems,

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tensively carried on, must alike adopt it, or the principle immediately assumes an unexceptionable character; and nations liable to be affected by it must provide means to counteract the effects of a sudden drain of the usual circulating medium, because the absence of a great quantity of the medium alters the price of exchange, or relative exchange of current money for necessary labor and subsistence, and depreciates other property.

such as, "*That silver, and not gold, should be the standard money or coin.*"

"*That copper is an unfit material for money.*"

And "*That paper circulating as, and called artificial money, is detrimental.*"

Yet as these doctrines seem to proceed from considering bullion, and money, or coin, in a different light from what we apprehend and have laid down, we will observe,

18. That it matters not whether silver or gold be called standard money; but it seems most rational, that the most scarce and precious metal should be the unit or standard.

19. That as to copper, it is as fit for money or a counter, as gold and silver, provided it be coined of a proper weight and fineness: and just so much will be useful, as will serve to make up small parts in exchanges between man and man.

20. That as to paper money, it is far from being detrimental; on the contrary, it is highly profitable, as its quick passing between mankind, instead of telling over, or weighing metal in coin, or bullion, is a gain of what is most precious in life, which is time. And there is nothing clearer than that those who must be concerned in counting and weighing, being at liberty to employ themselves on other purposes, are an addition of hands in the community.

The idea of the too great extension of credit, by the circulation of paper for money, is evidently as

erroneous as the doctrine of the non-exportation of gold and silver in bullion or coin: for were it not certain, that paper could command the equivalent of its agreed-for value, or that gold and silver in bullion or coin exported, would be returned in the course of trade in some other merchandise, neither paper would be used or the metals exported. It is by means of the produce of the land, and the happy situation of this island, joined to the industry of its inhabitants, that those much-adored metals, gold and silver, have been procured: and so long as the sea does not overflow the land, and industry continues, so long will those metals not be wanting. And paper in the general chain of credit and commerce, is as useful as they are, since the issuers or coiners of that paper are understood to have some equivalent to answer for what the paper is valued at: and no metal or coin can do more than find its value.

Moreover, as incontestable advantages of paper, we must add, that the charge of coining or making it, is by no means proportionate to that of coining of metals: nor is it subject to waste by long use, or impaired by adulteration, sweating, or filing, as coins may.

A THOUGHT CONCERNING THE SUGAR ISLANDS.

SHOULD it be agreed, and become a part of the law of nations, that the cultivators of the earth

are not to be molested or interrupted in their peaceable and useful employment, the inhabitants of the sugar islands would come under the protection of such a regulation, which would be a great advantage to the nations who at present hold those islands, since the cost of sugar to the consumer in those nations consists not only in the price he pays for it by the pound, but in the accumulated charge of all the taxes he pays in every war to fit out fleets and maintain troops for the defence of the islands that raise the sugar, and the ships that bring it home. But the expense of treasure is not all. A celebrated philosophical writer remarks, that when he considered the wars made in Africa for prisoners to raise sugar in America, the numbers slain in those wars, the numbers that, being crowded in ships, perish in the transportation, and the numbers that die under the severities of slavery, he could scarce look on a morsel of sugar without conceiving it spotted with human blood. If he had considered also the blood of one another which the white natives shed in fighting for those islands, he would have imagined his sugar not as spotted only, but as thoroughly dyed red. On these accounts I am persuaded that the subjects of the Emperor of Germany, and the Empress of Russia, who have no sugar islands, consume sugar cheaper at Vienna and Moscow, with all the charge of transporting it, after its arrival in Europe, than the citizens of London and

Paris. And I sincerely believe, that if France and England were to decide by throwing dice, which should have the whole of their sugar islands, the loser in the throw would be the gainer. The future expense of defending them would be saved: the sugars would be bought cheaper by all Europe if the inhabitants might make it without interruption; and whoever imported the sugar, the same revenue might be raised by duties at the custom-house of the nation that consumed it. And on the whole, I conceive it would be better for the nations now possessing sugar colonies, to give up their claim to them, let them govern themselves, and put them under the protection of all the powers of Europe as neutral countries open to the commerce of all, the profit of the present monopolies being by no means equivalent to the expense of maintaining them.

REMARKS, written by B. FRANKLIN, with a pencil, on the margin of a REPORT of JUDGE FOSTER, containing that Judge's argument in favor of the RIGHT OF IMPRESSING SEAMEN.

Extract from the Report, page 157, 158. *Edition* 1762.

"THE only question at present is, whether mariners, persons who have freely chosen a seafaring life, persons whose education and employment have fitted them for the service, and inured them

to it, whether such persons may not be legally pressed into the service of the crown, whenever the public safety requireth it: *ne quid detrimenti respublica capiat.*

"For my part, I think they may. I think the crown hath a right to command the service of these people whenever the public safety calleth for it. The same right that it hath to require the personal[1] service of every man able[2] to bear arms in case of a sudden invasion or formidable insurrection. The right in both cases is founded on one and the same principle, the necessity of the case in order to the preservation of the whole.

"It would be time very ill spent to go about to prove that this nation can never be long in a state of safety, our coast defended, and our trade pro-

[1] This personal service, in cases of extreme necessity, is a principal branch of the allegiance every subject of England oweth to the crown. See 11 Hen. VII. c. 1. 1 Ed. III. c. 5. 16, 17. Car. I. c. 28.

Remarks.

[2] The conclusion here from the *whole* to a *part*, does not seem to be good logic. When the personal service of *every man* is called for, there the burthen is equal. Not so, when the service of part is called for, and others excused. If the alphabet should say, let us all fight for the defence of the whole; that is equal, and may therefore be just. But if they should say, let A, B, C, and D, go and fight for us, while we stay at home and sleep in whole skins; that is not equal, and therefore cannot be just.

tected, without a naval force equal to all the emergencies that may happen. And how can we be secure of such a force? The keeping up the same naval force in time of peace, which will be absolutely necessary for our security in time of war, would be an absurd, a fruitless, and a ruinous expense.

"The only course then left, is for the crown to employ[1] upon emergent occasions, the mariners bred up in the merchant's service.

"And as for the mariner himself, he when taken into the service of the crown only changeth masters for a time: *his service and employment*[2] continue the very same, with this advantage, that the dangers of the sea and enemy are not so great in the service of the crown as in that of the merchant.

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[1] *Employ*—if you please. The word signifies engaging a man to work for me by offering him such wages as are sufficient to induce him to prefer my service. This is very different from *compelling* him to work for me *on such terms as I think proper*.

[2] "*His service and employment continue the very same*," *&c.* These are false facts. *His service and employment* are not the same. Under the merchant he goes in an unarmed vessel not obliged to fight, but only to transport merchandise. In the king's service he is obliged to fight, and to hazard all the dangers of battle. Sickness on board the king's ships is also more common and more mortal. The merchant's service too he can quit at the end of a voyage, not the king's. Also the merchant's wages are much higher.

"I am very sensible[1] of the hardship the sailor suffereth from an impress in some particular cases, especially if pressed homeward-bound after a long voyage. But the merchants who hear me know, that an impress on outward-bound vessels would be attended with much greater inconveniencies to the trade of the kingdom; and yet that too is sometimes necessary. But where two evils present, a wise administration, if there be room for an option, will choose *the least.*[2]

"Page 159. War itself is a great evil, but it is chosen to avoid a greater. The practice of pressing is one of the mischiefs war bringeth with it. But *it is a maxim in law, and good policy too, that private mischiefs must be borne with patience for preventing a national calamity.*[3] And as no greater calamity

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[1] "*I am very sensible,*" &c. Here are two things put in comparison that are not comparable, viz. injury to seamen, and inconvenience to trade. Inconvenience to the whole trade of a nation will not justify injustice to a single seaman. If the trade would suffer without his service, it is able and ought to be willing to offer him such wages as may induce him to afford his services voluntarily.

[2] "*The least.*" The least evil in case seamen are wanted, is to give them such wages as will induce them to inlist voluntarily. Let this evil be divided among the whole nation, by an equal tax to pay such wages.

[3] Where is this maxim in law and good policy to be found? And how came that to be a maxim which is not consistent with common sense? If the maxim had been, that private mischiefs which prevent a national calamity ought to be generously com-

can befal us than to be weak and defenceless at sea in a time of war, so I do not know that the wisdom of the nation hath hitherto found out any method of manning our navy less inconvenient[1] than pressing; and at the same time, equally sure and effectual.

"The expedient of a voluntary register, which was attempted in king William's time, had no effect.

"And some late schemes I have seen, appear to me more inconvenient to the mariner, and more inconsistent with the principles of liberty, than the practice of pressing: and what is still worse, they are in my opinion totally impracticable.[2]

"Thus much I thought proper to say upon the foot of reason and public utility, before I come to speak directly to the point of law.

"Page 159. The crown's right of impressing seamen is grounded upon common law.[3]

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pensated by that nation, one might have understood it. But that such private mischiefs are only to be borne with patience, is absurd.

[1] "*Less inconvenient.*" Less inconvenient to whom? To the rich indeed, who ought to be taxed. No mischief *more* inconvenient to poor seamen could possibly be contrived.

[2] Twenty ineffectual or inconvenient schemes will not justify one that is unjust.

[3] If impressing seamen is of right by common law, in Britain, slavery is then of right by common law there; there being no slavery worse than that sailors are subjected to.

"Ibid. The result of evident necessity.[1]

"Page 160. There are many precedents of writs for pressing.

"Some are for pressing ships;

"Others for pressing mariners;

"And others for pressing ships and mariners.

"This general view will be sufficient to let us into the nature of these precedents. And though the affair of pressing ships is not now before me, yet I could not well avoid mentioning it, because many of the precedents I have met with and must cite, go as well to that, as to the business of pressing mariners. And taken together, they serve to show the power the crown hath constantly exercised over the whole naval force of the kingdom as well shipping as mariners, whenever the public service required it.

"This however must be observed, that no man served the crown in either case at his own expense. Masters and mariners received *full wages*,[2] and owners were constantly paid a full freight.

"Page 173. Do not these things incontestably presuppose the expediency, the necessity, and the

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[1] Pressing not so, if the end might be answered by giving higher wages.

[2] *Mariners received full wages.* Probably the same they received in the merchant's service. Full wages to a seaman in time of war, are the wages he has in the merchant's service in war time. But half such wages is not given in the king's ships to impressed seamen.

legality of an impress in general? If they do not, one must entertain an opinion of the legislature acting and speaking in this manner, which it *will not be decent* for me to *mention* in this place.[1]

"Page 174. I readily admit that an impress is a restraint upon the natural liberty of those who are liable to it. But it must likewise be admitted, on the other hand, that every restraint upon natural liberty is not *eo nomine* illegal, or at all inconsistent with the principles of *civil* liberty. And if the restraint, be it to what degree soever, appeareth to be necessary to the good and welfare of the whole, and to be warranted by statute law, as well as immemorial usage, it cannot be complained of otherwise than as a private mischief;[2] which,

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[1] I will risk that indecency, and mention it. They were not honest men; they acted unjustly by the seamen, (who have no vote in elections, or being abroad cannot use them if they have them) to save their own purses and those of their constituents. Former parliaments acted the same injustice towards the laboring people, wno had not forty shillings a-year in lands: after depriving them wickedly of their right to vote in elections, they limited their wages, and compelled them to work at such limited rates, on penalty of being sent to houses of correction. Sec. 8. H. VI. Chap. 7 and 8.

[2] "*It cannot be complained of otherwise than as a* PRIVATE MISCHIEF, *which* MUST *be submitted to for avoiding a public inconvenience.*"—I do not see the propriety of this *must*. The private mischief is the loss of liberty and hazard of life, with only half wages, to a great number of honest men. The public inconvenience is merely a higher rate of seamen's wages.

as I said at the beginning, must under all governments whatsoever be submitted to for avoiding a public inconvenience.[1]

He who thinks such private injustice *must* be done to avoid public inconvenience, may understand *law*, but seems imperfect in his knowledge of *equity*. Let us apply this author's doctrine to his own case. It is for the public service that courts should be had and judges appointed to administer the laws. The judges should be bred to the law and skilled in it, but their great salaries are a *public inconvenience*. To remove the inconvenience, let press-warrants issue to arrest and apprehend the best lawyers, and compel them to serve as judges for half the money they would have made at the bar. Then tell them, that though this is to them a private mischief, it *must* be submitted to for avoiding a *public inconvenience*. Would the learned judge approve such use of his doctrine?

[1] When the author speaks of impressing, page 158, he diminishes the horror of the practice as much as possible, by presenting to the mind one sailor only suffering a hardship, as he tenderly calls it, in some *particular cases* only; and he places against this private mischief the inconvenience to the trade of the kingdom. But if, as I suppose is often the case, the sailor who is pressed and obliged to serve for the defence of this trade at the rate of 25*s*. a month, could have 3*l*. 15*s*. in the merchant's service, you take from him 50*s*. a month; and if you have 100,000 in your service, you rob that honest part of society and their poor families of 250,000*l*. per month, or three millions a year, and at the same time oblige them to hazard their lives in fighting for the defence of your trade; to the defence of which all ought indeed to contribute, (and sailors among the rest) in proportion to their profits by it; but this three millions is more than their share, if they did not pay with their persons; and when you force that, methinks you should excuse the other.

"Page 177. For I freely declare, that *ancient precedents* alone, unless supported by *modern prac-*

But it may be said, to give the king's seamen merchant's wages, would cost the nation too much, and call for more taxes. The question then will amount to this; whether it be just in a community that the richer part should compel the poorer to fight for them and their properties, for such wages as they think fit to allow, and punish them if they refuse? Our author tells us it is *legal*. I have not law enough to dispute his authorities, but I cannot persuade myself it is *equitable*. I will however own for the present, that pressing may be lawful when necessary; but then I contend that it may be used so as to produce the same good effect, *the public security*, without doing so much horrible injustice as attends the impressing common seamen. In order to be better understood, I would premise two things. 1st. That voluntary seamen might be had for the service, if they were sufficiently paid. The proof of this is, that to serve in the same ships, and incur the same dangers, you have no occasion to impress captains, lieutenants, second lieutenants, midshipmen, pursers, nor any other officers. Why, but that the profit of their places, or the emoluments expected, are sufficient inducements? The business then is by impressing to find money sufficient to make the sailors all volunteers, as well as their officers; and this without any fresh burthen upon trade. The 2nd of my premises is, that 25*s*. a month, with his share of the salt beef, pork, and peas-pudding, being found sufficient for the subsistence of a hard-working seaman, it will certainly be so for a sedentary scholar or gentleman. I would then propose to form a treasury, out of which encouragement to seamen should be paid. To fill this treasury I would impress a number of civil officers who at present have great salaries, oblige them to serve in their respective offices for 25*s*. per month, with their share of the mess

tice, weigh very little with me in questions of this nature.[1]

"Page 179. I make no apology for the length of my argument, because I hope the importance

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provisions, and throw the rest of their salaries into the seaman's treasury. If such a press-warrant was given me to execute, the first person I would press should be a recorder of Bristol, or a Mr. Justice Foster, because I might have need of his edifying example, to show how such impressing ought to be borne with; for he would certainly find, that though to be reduced to 25*s*. per month might be a *private mischief*, yet that agreeably to his *maxim* of *law* and good policy, *it ought to be borne with patience* for preventing a national calamity. Then I would press the rest of the judges; and, opening the Red Book, I would press every civil officer of government from 50*l*. a year up to 50,000*l*., which would throw an immense sum into our treasury; and these gentlemen could not well complain, since they would receive their 25*s*. a month and their rations, and that too without being obliged to fight. Lastly, I think I would impress the king, and confiscate his salary; but, from an ancient prejudice I have in favor of that title, I would allow him the gentleman merchant's pay. I could not well go farther in his favor; for to say the truth, I am not quite satisfied of the necessity or utility of that office in Great Britain, as I see many florishing states in the world governed well and happily without it.

[1] The *modern practice*, supported by ancient *precedents*, weighs as little with me. Both the one and the other only show that the constitution is yet imperfect, since in so general a case it doth not secure liberty, but destroys it; and the parliaments are unjust, conniving at oppression of the poor, where the rich are to be gainers or savers by such oppression.

of the question will be thought *a sufficient* excuse for me in this respect."[1]

ON THE CRIMINAL LAWS, AND THE PRACTICE OF PRIVATEERING.

To B. Vaughan, Esq.

My dear Friend, *March* 14, 1785.

Among the pamphlets you lately sent me, was one intitled, "Thoughts on Executive Justice." In return for that, I send you a French one on the same subject, "Observations concernant l'Exécution de l'Article II. de la Déclaration sur le Vol." They are both addressed to the judges, but written, as you will see, in a very different spirit. The English author is for hanging *all* thieves. The Frenchman is for proportioning punishments to offences.

If we really believe, as we profess to believe, that the law of Moses was the law of God, the dictate of divine wisdom, infinitely superior to human; on what principles do we ordain death as the punishment of an offence, which, according to that law, was only to be punished by a restitution of fourfold? To put a man to death for an offence which

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[1] The author could not well have made his argument shorter. It required a long discourse to throw dust in the eyes of common sense, confound all our ideas of right and wrong, make black seem white, and the worse appear the better opinion.

does not deserve death, is it not a murder? And, as the French writer says, "*Doit-on punir un délit contre la société, par un crime contre la nature?*"

Superfluous property is the creature of society. Simple and mild laws were sufficient to guard the property that was merely necessary. The savage's bow, his hatchet, and his coat of skins, were sufficiently secured, without law, by the fear of personal resentment and retaliation. When, by virtue of the first laws, part of the society accumulated wealth and grew powerful, they enacted others more severe, and would protect their property at the expense of humanity. This was abusing their power, and commencing a tyranny. If a savage, before he entered into society, had been told,—"Your neighbor by this means may become owner of an hundred deer; but if your brother, or your son, or yourself, having no deer of your own, and being hungry, should kill one, an infamous death must be the consequence;" he would probably have preferred his liberty, and his common right of killing any deer, to all the advantages of society that might be proposed to him.

That it is better a hundred guilty persons should escape than that one innocent person should suffer, is a maxim that has been long and generally approved; never, that I know of, controverted. Even the sanguinary author of the *Thoughts* agrees to it, adding well, "that the very thought of *injured* innocence, and much more that of *suffering* inno-

cence, must awaken all our tenderest and most compassionate feelings, and at the same time raise our highest indignation against the instruments of it. But," he adds, "there is no danger of *either*, from a strict adherence to the laws."—Really! Is it then impossible to make an unjust law? and if the law itself be unjust, may it not be the very "instrument" which ought "to raise the author's and every body's highest indignation?" I see, in the last newspapers from London, that a woman is capitally convicted at the Old Bailey, for privately stealing out of a shop some gauze, value fourteen shillings and threepence: is there any proportion between the injury done by a theft, value fourteen shillings and threepence, and the punishment of a human creature, by death, on a gibbet? Might not the woman, by her labor, have made the reparation ordained by God, in paying fourfold? Is not all punishment inflicted beyond the merit of the offence, so much punishment of innocence? In this light, how vast is the annual quantity of not only *injured*, but *suffering* innocence, in almost all the civilised states of Europe!

But it seems to have been thought, that this kind of innocence may be punished by way of *preventing* crimes. I have read, indeed, of a cruel Turk in Barbary, who, whenever he bought a new Christian slave, ordered him immediately to be hung up by the legs, and to receive a hundred blows of a cudgel on the soles of his feet, that the

severe sense of the punishment, and fear of incurring it thereafter, might prevent the faults that should merit it. Our author himself would hardly approve entirely of this Turk's conduct in the government of slaves; and yet he appears to recommend something like it for the government of English subjects, when he applauds the reply of Judge Burnet to the convict horse-stealer, who, being asked what he had to say why judgment of death should not pass against him, and answering, that it was hard to hang a man for *only* stealing a horse, was told by the judge, "Man, thou art not to be hanged *only* for stealing a horse, but that horses may not be stolen." The man's answer, if candidly examined, will I imagine appear reasonable, as being founded on the eternal principle of justice and equity, that punishments should be proportioned to offences; and the judge's reply brutal and unreasonable, though the writer "wishes all judges to carry it with them whenever they go the circuit, and to bear it in their minds as containing a wise reason for all the penal statutes, which they are called upon to put in execution. "It at once illustrates," says he, "the true grounds and reasons of all capital punishments whatsoever, namely, that every man's property, as well as his life, may be held sacred and inviolate." Is there then no difference in value between property and life? If I think it right, that the crime of murder should be punished with death, not only as an

equal punishment of the crime, but to prevent other murders, does it follow that I must approve of inflicting the same punishment for a little invasion on my property by theft? If I am not myself so barbarous, so bloody-minded and revengeful, as to kill a fellow-creature for stealing from me fourteen shillings and threepence, how can I approve of a law that does it? Montesquieu, who was himself a judge, endeavors to impress other maxims.

He must have known what humane judges feel on such occasions, and what the effects of those feelings; and so far from thinking that severe and excessive punishments prevent crimes, he asserts, as quoted by our French writer, that

"*L'atrocité des loix en empêche l'exécution.*

"*Lorsque la peine est sans mesure, on est souvent obligé de lui préférer l'impunité.*

"*La cause de tous les relâchemens vient de l'impunité des crimes, et non de la modération des peines.*"

It is said by those who know Europe generally, that there are more thefts committed and punished annually in England than in all the other nations put together. If this be so, there must be a cause or causes for such depravity in your common people. May not one be the deficiency of justice and morality in your national government, manifested in your oppressive conduct to your subjects, and unjust wars on your neighbors? View the long-persisted in, unjust monopolising treatment of Ireland at length acknowledged! View the plun-

dering government exercised by your merchants in the Indies; the confiscating war made upon the American colonies; and, to say nothing of those upon France and Spain, view the late war upon Holland, which was seen by impartial Europe in no other light than that of a war of rapine and pillage; the hopes of an immense and easy prey being its only apparent and probably its true and real motive and encouragement. Justice is as strictly due between neighbor nations as between neighbor citizens. A highwayman is as much a robber when he plunders in a gang as when single; and a nation that makes an unjust war, is only a *great gang*. After employing your people in robbing the Dutch, strange is it, that being put out of that employ by peace, they still continue robbing and rob one another! *Piraterie*, as the French call it, or privateering, is the universal bent of the English nation, at home and abroad, wherever settled. No less than seven hundred privateers were, it is said, commissioned in the last war! These were fitted out by merchants, to prey upon other merchants, who had never done them any injury. Is there probably any one of those privateering merchants of London, who were so ready to rob the merchants of Amsterdam, that would not as readily plunder another London merchant of the next street, if he could do it with the same impunity? The avidity, the *alieni appetens*, is the same; it is the fear alone of the gallows that makes the dif-

ference. How then can a nation, which, among the honestest of its people, has so many thieves by inclination, and whose government encouraged and commissioned no less than seven hundred gangs of robbers; how can such a nation have the face to condemn the crime in individuals, and hang up twenty of them in a morning? It naturally puts one in mind of a Newgate anecdote:—One of the prisoners complained, that in the night somebody had taken his buckles out of his shoes;—"What, the devil!" says another, "have we then *thieves* among us?—It must not be suffered;—let us search out the rogue, and pump him to death."

There is, however, one late instance of an English merchant who will not profit by such ill-gotten gain. He was, it seems, part-owner of a ship, which the other owners thought fit to employ as a letter of marque, and which took a number of French prizes. The booty being shared, he has now an agent here inquiring, by an advertisement in the Gazette, for those who suffered the loss, in order to make them, as far as in him lies, restitution. This conscientious man is a Quaker. The Scotch Presbyterians were formerly as tender; for there is still extant an ordinance of the town-council of Edinburgh, made soon after the reformation, "forbidding the purchase of prize goods, under pain of losing the freedom of the burgh for ever, with other punishment at the will of the magistrate; the practice of making prizes being con-

trary to good conscience, and the rule of treating Christian brethren as we would wish to be treated; and such goods *are not to be sold by any godly men within this burgh.*" The race of these godly men in Scotland is probably extinct, or their principles abandoned, since, as far as that nation had a hand in promoting the war against the colonies, prizes and confiscations are believed to have been a considerable motive.

It has been for some time a generally received opinion, that a military man is not to inquire whether a war be just or unjust; he is to execute his orders. All princes who are disposed to become tyrants, must probably approve of this opinion, and be willing to establish it; but is it not a dangerous one? since, on that principle, if the tyrant commands his army to attack and destroy, not only an unoffending neighbor nation, but even his own subjects, the army is bound to obey. A negro slave, in our colonies, being commanded by his master to rob or murder a neighbor, or do any other immoral act, may refuse, and the magistrate will protect him in his refusal. The slavery then of a soldier is worse than that of a negro! A conscientious officer, if not restrained by the apprehension of its being imputed to another cause, may indeed resign, rather than be employed in an unjust war; but the private men are slaves for life; and they are perhaps incapable of judging for themselves. We can only lament their fate, and still

more that of a sailor, who is often dragged by force from his honest occupation, and compelled to imbrue his hands in, perhaps, innocent blood. But methinks it well behoves merchants (men more enlightened by their education, and perfectly free from any such force or obligation) to consider well of the justice of a war, before they voluntarily engage a gang of ruffians to attack their fellow-merchants of a neighboring nation, to plunder them of their property, and perhaps ruin them and their families, if they yield it; or to wound, maim, or murder them, if they endeavor to defend it. Yet these things are done by Christian merchants, whether a war be just or unjust; and it can hardly be just on both sides. They are done by English and American merchants, who, nevertheless, complain of private theft, and hang by dozens the thieves they have taught by their own example.

It is high time, for the sake of humanity, that a stop were put to this enormity. The United States of America, though better situated than any European nation to make profit by privateering, (most of the trade of Europe, with the West Indies, passing before their doors) are, as far as in them lies, endeavoring to abolish the practice, by offering, in all their treaties with other powers, an article, engaging solemnly, that, in case of future war, no privateer shall be commissioned on either side; and that unarmed merchant-ships, on both

sides, shall pursue their voyages unmolested.[1] This will be a happy improvement of the law of

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[1] This offer having been accepted by the late king of Prussia, a treaty of amity and commerce was concluded between that monarch and the United States, containing the following humane, philanthropic article; in the formation of which Dr. Franklin, as one of the American plenipotentiaries, was principally concerned, viz.

ART. XXIII.

If war should arise between the two contracting parties, the merchants of either country, then residing in the other, shall be allowed to remain nine months to collect their debts and settle their affairs, and may depart freely, carrying off all their effects without molestation or hindrance; and all women and children, scholars of every faculty, cultivators of the earth, artisans, manufacturers, and fishermen, unarmed and inhabiting unfortified towns, villages, or places, and in general all others, whose occupations are for the common subsistence and benefit of mankind, shall be allowed to continue their respective employments, and shall not be molested in their persons, nor shall their houses and goods be burnt, or otherwise destroyed, nor their fields wasted, by the armed force of the enemy into whose power, by the events of war, they may happen to fall; but if any thing is necessary to be taken from them for the use of such armed force, the same shall be paid for at a reasonable price. And all merchants and trading vessels employed in exchanging the products of different places, and thereby rendering the necessaries, conveniencies, and comforts of human life more easy to be obtained, and more general, shall be allowed to pass free and unmolested; and neither of the contracting powers shall grant or issue any commission to any private armed vessels, empowering them to take or destroy such trading vessels, or interrupt such commerce.

nations. The humane and the just cannot but wish general success to the proposition. With unchangeable esteem and affection, ever yours,

B. FRANKLIN.

ON THE ELECTIVE FRANCHISES ENJOYED BY THE SMALL BOROUGHS IN ENGLAND.

(To Sir Charles Wyvill.)

SIR, *Passy, June* 16, 1785.

I send you herewith the sketch I promised you. Perhaps there may be some use in publishing it: for, if the power of choosing now in the boroughs continues to be allowed as a right, they may think themselves more justifiable in demanding more for it, or holding back longer than they would, if they find that it begins to be considered as an abuse. I have the honor to be, &c. B. FRANKLIN.

PAPER ENCLOSED IN THE FOREGOING LETTER TO SIR C. WYVILL.

June 16, 1785.

No man, or body of men, in any nation, can have a just right to any privilege or franchise not common to the rest of the nation, without having done the nation some service equivalent, for which the franchise or privilege was the recompense or consideration.

No man, or body of men, can be justly deprived of a common right, but for some equivalent offence or injury done to the society in which he enjoyed that right.

If a number of men are unjustly deprived of a common right, and the same is given in addition to the common rights of another number, who have not merited such addition, the injustice is double.

Few, if any, of the boroughs in England, ever performed any *such* particular service to the nation, entitling them to what they now claim as a privilege in elections.

Originally, in England, when the king issued his writs calling upon counties, cities, and boroughs, to depute persons who should meet him in parliament, the intention was to obtain by that means more perfect information of the general state of the kingdom, its faculties, strength, and disposition; together with the advice their accumulated wisdom might afford him in "such arduous affairs of the realm" as he had to propose. And he might reasonably hope that measures approved by the deputies in such an assembly would, on their return home, be by them well explained, and rendered agreeable to their constituents and the nation in general. At that time, being sent to parliament was not considered as being put into the way of preferment, or increase of fortune; therefore no bribe was given to obtain the appoint-

ment. The deputies were to be paid wages by their constituents: therefore the being obliged to send and pay was considered rather as a duty than a privilege. At this day, in New England, many towns who may, and ought, to send members to the assembly, sometimes neglect to do it; they are then summoned to answer for their neglect, and fined if they cannot give a good excuse; such as some common misfortune, or some extraordinary public expense, which disabled them from affording, conveniently, the necessary wages. And the wages allowed being barely sufficient to defray the deputy's expense, no solicitations are used to be chosen.

In England, as soon as the being sent to parliament was found to be a step towards acquiring both honor and fortune, solicitations were practised, and where they were insufficient, money was given. Both the ambitious and avaricious became candidates. But to solicit the poor laborer for his vote beirg humiliating to the proud man, and to pay for it hurting the lover of money, they, when they met, joined in an act to diminish both these inconveniencies, by depriving the poor of the right of voting, which certainly they were not empowered to do by the electors their constituents, the majority of whom were probably people of little property. The act was, therefore, not only unjust, but void. These lower people were imme-

diately afterwards oppressed by another act, empowering the justices to fix the hire of day laborers and their hours of work, and to send them to the house of correction if they refused to work for such hire; which was deposing them from their condition of freemen, and making them literally slaves.

But this was taking from *many* freemen a *common right*, and confining it to a *few*. To give it back again to the many is a different operation. Of this the few have no just cause to complain, because they still retain the common right they always had, and they lose only the exclusive additional power which they ought never to have had. And if they used it when they had it, as a means of obtaining money, they should in justice, were it practicable, be obliged to refund and distribute such money among those who had been so unjustly deprived of their right of voting, or forfeit it to the public.

Corporations, therefore, or boroughs, who from being originally called to send deputies to parliament, when it was considered merely as a duty, and not as a particular privilege, and therefore was never purchased by any equivalent service to the public, continue to send, now that by a change of times it affords them profit in bribes, or emoluments of various kinds, have in reality *no right* to such advantages; which are besides in effect prejudicial to the nation, some of those who buy thinking they may also sell.

They should therefore, in justice, be immediately deprived of such pretended right, and reduced to the condition of common freemen.

But they are perhaps too strong, and their interest too weighty, to permit such justice to be done. And a regard for public good in these people, influencing a voluntary resignation, is not to be expected.

If that be the case, it may be necessary to submit to the power of present circumstances, passions, and prejudices, and purchase, since we can do no better, their consent; as men, when they cannot otherwise recover property unjustly detained from them, advertise a reward to whoever will restore it, promising that no questions shall be asked.

B. F.

LETTER FROM SIR CHARLES WYVILL, IN ANSWER TO THE FOREGOING.

SIR, *Paris, June* 17, 1785.

I have received the honor of your letter of the 16th instant, accompanied with a paper, in which you have proved, by a short train of clear and satisfactory reasoning, that the elective franchise now enjoyed by the small boroughs in England, is not an absolute right, which can only be forfeited on condition of misusage, but that it is a privilege conferred upon them in different periods of our history with partiality, and in a manner injurious to

the common right of representation; and consequently, that it is a privilege justly resumable by the state, without the consent of such boroughs previously obtained, without any previous proof of their delinquency, or any compensation for their abolished franchise: at the same time, you have admitted the expediency, in the present state of our constitution, and under the various disadvantages attending an attempt to restore it, that a pecuniary offer should be proposed, as an inducement to the small boroughs to make a voluntary surrender of their obnoxious privilege.

Accept, sir, my best thanks for this very kind communication of your sentiments on a subject of much importance to the happiness of England. From their own intrinsic solidity, those sentiments must have great weight with every unprejudiced mind, even if it should not be thought advisable to apprise the public. They are the sentiments of a man to whose ability and persevering virtue the American States are principally indebted for their political salvation. But highly as I esteem the wisdom of your opinion and advice, I place a still higher value on that philanthropy which has induced you to bestow so much attention on this subject, in the midst of your many urgent avocations, when just on the point of leaving Europe to return to America; I consider this not only as a mark of your general benevolence, but as a proof that your peculiar good-will to England, lately

our common country, has neither been diminished by any personal disgust, nor impaired by the hostilities of an unhappy civil war. And I trust that, on this occasion, your benevolence has not been misplaced; since the advocates for a reformation of the English parliament have been, I believe, without exception, zealous opponents of the American war; and the success of their attempt to improve the constitution of England, may possibly conduct our two countries, in due time, to that modified reunion which recent events will admit, and which you seem to agree with me in thinking would be equally honorable and advantageous to both.

I am, with the highest respect, your obliged and most obedient servant, C. WYVILL.

MILITIA PREFERABLE TO REGULAR TROOPS.

Abbé Morellet's Questions and B. Franklin's Answers.

Je prie Monsieur Franklin de vouloir bien répondre aux questions suivantes by a *yes* or *no.*

Croit-il que les Etats Unis puissent dans la suite et après leur indépendance reconnue se passer de troupes régulières toujours sur pied?—Yes.

Feront-ils mieux de n'avoir que des milices nationales?—Certainly.

Des milices coûteront-elles moins cher à l'état ou plutôt à la nation; car ne peut-on pas dire que

dans un état de choses où tous les citoyens doivent s'exercer à porter les armes il y a en fin de compte, en perte de tems, en dépenses pour l'armement, pour l'habillement, pour le rassemblement des troupes à certains tems de l'année, &c. une dépense réelle plus grande que celle qu'il faudroit pour tenir sur pied un petit nombre de troupes régulières?

Supposing a general militia to be equally expensive with a body of regular troops, yet the militia is preferable; because the whole being especially disciplined, has nothing to fear from a part.

Monsieur Franklin croit-il qu'on puisse entretenir en Amérique un corps de troupes sur pied dans chaque province confédérée sans mettre la liberté en danger?

Europe was without regular troops till lately. One powerful prince keeping an army always on foot makes it necessary for his neighbor to do the same to prevent surprise. We have no such dangerous neighbors in America. We shall probably keep magazines of arms and ammunition always filled, and no European power will ever find us so unprovided as England found us at the beginning of this war, or can prepare to invade us with a sufficient force in so short a time as not to give us time sufficient to discipline force sufficient to repel the invader.

Mr. F. therefore thinks, that to avoid not only the expense, but the danger of keeping up a body

of regular troops in time of peace, none of the states separately will do it, nor the congress for the whole.

PROJECT FOR PREVENTING WARS.

(Extract of a Letter to Dr. Ingenhausz.)

Philadelphia, February 11, 1788.

"I lament with you the prospect of a horrid war, which is likely to engage a great part of mankind. There is so little good gained and so much mischief done generally by wars, that I wish the imprudence of undertaking them were more evident to princes; in which case I think they would be less frequent. If I were counsellor to the Empress of Russia, and found that she desired to possess some part of the dominions of the Grand Signior, I should advise her to compute what the annual taxes raised from that territory may amount to, and make him an offer of buying it at the rate of paying for it twenty years' purchase. And if I were his counsellor, I should advise him to take the money, and cede the dominion of that territory. For I am of opinion, that a war to obtain it will cost her more than that sum, and the event uncertain; and the defence of it will cost him as much; and, not having embraced the offer, his loss is double. But to make and accept such an offer, these potentates should be both of them reason able creatures; and free from the ambition of

glory, &c. which perhaps is too much to be supposed.[1]

"I am glad that peace is likely to be established in your native country,[2] with so little expense of blood, though it be done in a manner not agreeable to a great part of the nation. If the French had entered with the Prussians, and made it the seat of war, the mischief would have been infinite."

SOME GOOD WHIG PRINCIPLES.

[*A printed paper, of which the following is a copy, was found among Dr. Franklin's papers, indorsed by him as above.*]

DECLARATION of those RIGHTS of the Commonalty of Great Britain, *without which they cannot be* FREE.

It is declared,

First, That the government of this realm, and the making of laws for the same, ought to be lodged in the hands of King, Lords of parliament, and Representatives of *the whole body* of the Freemen of this realm.

Secondly, That *every man* of the commonalty (excepting infants, insane persons, and criminals,)

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[1] See Letter to B. Vaughan, Esq. Oct. 24, 1788.—PRIVATE CORRESPONDENCE, Part I.

[2] Holland.

is, of common right, and by the laws of God, *a freeman*, and entitled to the free enjoyment of *liberty*.

Thirdly, That liberty, or freedom, consists in having *an actual share* in the appointment of those who frame the laws, and who are to be the guardians of every man's life, property, and peace; for, the *all* of one man is as dear to him as the *all* of another; and the poor man has an *equal* right, but *more* need to have representatives in the legislature than the rich one.

Fourthly, That they who have *no* voice nor vote in the electing of representatives, *do not enjoy* liberty; but are absolutely *enslaved* to those who *have* votes, and to their representatives; for, to be enslaved, is to have governors whom *other men have set over us*, and to be subject to laws *made by the representatives of others*, without having had representatives of our own to give consent in *our* behalf.

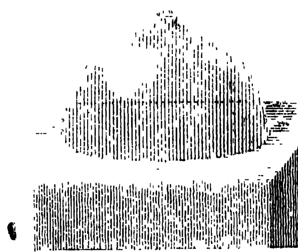
Fifthly, That *a very great majority* of the commonalty of this realm are denied the privilege of voting for representatives in parliament; and, consequently, they are enslaved to a *small number*, who do now enjoy the privilege exclusively to themselves; but who, it may be presumed, are far from wishing to continue in the exclusive possession of a privilege, by which their fellow-subjects are deprived of *common right*, of *justice*, of *liberty*; and which, if not communicated to all, must speed-

ily cause *the certain overthrow of our happy constitution*, and enslave us *all*.

And sixthly and lastly, We also say and do assert, that it is *the right* of the commonalty of this realm to elect a *new* House of Commons once in *every year*, according to the ancient and sacred laws of the land: because whenever a parliament continues in being for *a longer term*, very great numbers of the commonalty, who have arrived at years of manhood since the last election, and *therefore* have a right to be actually represented in the House of Commons, are then *unjustly deprived* of that right.

END OF PART III.

Plate 1.



PART IV.

PHILOSOPHICAL SUBJECTS.

DESCRIPTION OF A NEW MUSICAL INSTRUMENT COMPOSED OF GLASSES, CALLED THE ARMONICA.[1]

TO THE REV. FATHER BECCARIA.

REV. SIR, *London, July* 13, 1762.

I ONCE promised myself the pleasure of seeing you at Turin; but as that is not now likely to happen, being just about returning to my native country, America, I sit down to take leave of you (among others of my European friends that I cannot see) by writing.

I thank you for the honorable mention you have so frequently made of me in your letters to Mr. Collinson and others, for the generous defence you undertook and executed with so much success, of my electrical opinions; and for the valuable present you made me of your new work, from which

[1] See Plate 1.

I have received great information and pleasure. I wish I could in return entertain you with any thing new of mine on that subject; but I have not lately pursued it. Nor do I know of any one here that is at present much engaged in it.

Perhaps, however, it may be agreeable to you, as you live in a musical country, to have an account of the new instrument lately added here to the great number that charming science was before possessed of.—As it is an instrument that seems peculiarly adapted to Italian music, especially that of the soft and plaintive kind, I will endeavor to give you such a description of it, and of the manner of constructing it, that you or any of your friends may be enabled to imitate it, if you incline so to do, without being at the expense and trouble of the many experiments I have made in endeavoring to bring it to its present perfection.

You have doubtless heard the sweet tone that is drawn from a drinking-glass, by passing a wet finger round its brim. One Mr. Puckeridge, a gentleman from Ireland, was the first who thought of playing tunes, formed of these tones. He collected a number of glasses of different sizes, fixed them near each other on a table, and tuned them by putting into them water, more or less, as each note required. The tones were brought out by passing his fingers round their brims. He was unfortunately burnt here, with his instrument, in a fire which consumed the house he lived in. Mr.

E. Delaval, a most ingenious member of our Royal Society, made one in imitation of it, with a better choice and form of glasses, which was the first I saw or heard. Being charmed with the sweetness of its tones, and the music he produced from it, I wished only to see the glasses disposed in a more convenient form, and brought together in a narrower compass, so as to admit of a greater number of tones, and all within reach of hand to a person sitting before the instrument, which I accomplished, after various intermediate trials, and less commodious forms, both of glasses and construction, in the following manner.

The glasses are blown as near as possible in the form of hemispheres, having each an open neck or socket in the middle.[1] The thickness of the glass near the brim about a tenth of an inch, or hardly quite so much, but thicker as it comes nearer the neck, which in the largest glasses is about an inch deep, and an inch and half wide within, these dimensions lessening as the glasses themselves diminish in size, except that the neck of the smallest ought not to be shorter than half an inch. The largest glass is nine inches diameter, and the smallest three inches. Between these three are twenty-three different sizes, differing from each other a quarter of an inch in diameter. To make a single instrument there should be at least

[1] See Plate 1.—A

six glasses blown of each size; and out of this number one may probably pick thirty-seven glasses (which are sufficient for three octaves with all the semitones) that will be each either the note one wants or a little sharper than that note, and all fitting so well into each other as to taper pretty regularly from the largest to the smallest. It is true there are not thirty-seven sizes; but it often happens that two of the same size differ a note or half note in tone, by reason of a difference in thickness, and these may be placed one in the other without sensibly hurting the regularity of the taper form.

The glasses being chosen, and every one marked with a diamond the note you intend it for, they are to be tuned by diminishing the thickness of those that are too sharp. This is done by grinding them round from the neck towards the brim, the breadth of one or two inches, as may be required; often trying the glass by a well-tuned harpsichord, comparing the tone drawn from the glass by your finger, with the note you want, as sounded by that string of the harpsichord. When you come nearer the matter, be careful to wipe the glass clean and dry before each trial, because the tone is something flatter when the glass is wet, than it will be when dry;—and grinding a very little between each trial, you will thereby tune to great exactness. The more care is necessary in this, because if you go below your required tone, there

is no sharpening it again but by grinding somewhat off the brim, which will afterwards require polishing, and thus increase the trouble.

The glasses being thus tuned, you are to be provided with a case for them, and a spindle on which they are to be fixed. My case is about three feet long, eleven inches every way wide within at the biggest end, and five inches at the smallest end; for it tapers all the way, to adapt it better to the conical figure of the set of glasses. This case opens in the middle of its height, and the upper part turns up by hinges fixed behind. The spindle, which is of hard iron, lies horizontally from end to end of the box within, exactly in the middle, and is made to turn on brass gudgeons at each end. It is round, an inch diameter at the thickest end, and tapering to a quarter of an inch at the smallest.—A square shank comes from its thickest end through the box, on which shank a wheel is fixed by a screw. This wheel serves as a fly to make the motion equable, when the spindle, with the glasses, is turned by the foot like a spinning-wheel. My wheel is of mahogany, eighteen inches diameter, and pretty thick, so as to conceal near its circumference about 25lb. of lead.—An ivory pin is fixed in the face of this wheel, and about four inches from the axis. Over the neck of this pin is put the loop of the string that comes up from the moveable step to give it

motion. The case stands on a neat frame with four legs.

To fix the glasses on the spindle, a cork is first to be fitted in each neck pretty tight, and projecting a little without the neck, that the neck of one may not touch the inside of another when put together, for that would make a jarring.—These corks are to be perforated with holes of different diameters, so as to suit that part of the spindle on which they are to be fixed. When a glass is put on, by holding it stiffly between both hands, while another turns the spindle, it may be gradually brought to its place. But care must be taken that the hole be not too small, lest, in forcing it up, the neck should split; nor too large, lest the glass not being firmly fixed should turn or move on the spindle, so as to touch and jar against its neighboring glass. The glasses thus are placed one in another, the largest on the biggest end of the spindle, which is to the left hand; the neck of this glass is towards the wheel, and the next goes into it in the same position, only about an inch of its brim appearing beyond the rim of the first: thus proceeding, every glass when fixed shows about an inch of its brim (or three quarters of an inch, or half an inch, as they grow smaller) beyond the brim of the glass that contains it; and it is from these exposed parts of each glass that the tone is drawn, by laying a finger upon one of them as the spindle and glasses turn round.

My largest glass is G, a little below the reach of a common voice, and my highest G, including three complete octaves.—To distinguish the glasses the more readily to the eye, I have painted the apparent parts of the glasses within side, every semitone white, and the other notes of the octave with the seven prismatic colors, viz. C, red; D, orange; E, yellow; F, green; G, blue; A, indigo; B, purple; and C, red again;—so that glasses of the same color (the white excepted) are always octaves to each other.

This instrument is played upon, by sitting before the middle of the set of glasses as before the keys of a harpsichord, turning them with the foot, and wetting them now and then with a sponge and clean water. The fingers should be first a little soaked in water, and quite free from all greasiness; a little fine chalk upon them is sometimes useful, to make them catch the glass and bring out the tone more readily. Both hands are used, by which means different parts are played together.—Observe, that the tones are best drawn out when the glasses turn *from* the ends of the fingers, not when they turn *to* them.

The advantages of this instrument are, that its tones are incomparably sweet beyond those of any other; that they may be swelled and softened at pleasure by stronger or weaker pressures of the finger, and continued to any length; and that the instrument, being once well tuned, never again wants tuning

In honor of your musical language, I have borrowed from it the name of this instrument, calling it the Armonica. With great esteem and respect, I am, &c. B. FRANKLIN.

ANSWER TO SOME QUERIES OF MONSIEUR DUBOURG RESPECTING THE ARMONICA.

London, Dec. 8, 1772.

WHEN the glasses are ranged on the horizontal spindle, or, to make use of your expression, *enfilés*, and that each one is definitely fixed in its place,—the whole of the largest glass appears, at the extremity to the left;[1] the following one, nearly enclosed in the preceding one, shows only about an inch of its border, which advances so much further than the edge of the larger glass;—and so, in succession, each glass exceeds the one containing it, leaving by this placement an uncovered border on which the fingers may be applied. The glasses do not touch one another, but they are so near as not to admit a finger to pass between them; so that the interior border is not susceptible of being rubbed.

The finger is to be applied flat on the borders of the largest glasses, and on the borders of the smaller; but in part on the borders, and in part on the edges, of the glasses of an intermediate size.

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[1] See Plate 1.—B.

Nothing but experience can instruct with respect to this manutation, (*fingering*), because the different-sized glasses require to be touched differently—some nearer the edge, and others farther from it. A few hours' exercise will teach this.

B. F.

ON FIRE.

Craven Street, 1762.

DID you ever see people at work with spades and pickaxes, digging a cellar? When they have loosened the earth perhaps a foot deep, that loose earth must be carried off, or they can go no deeper; it is in their way, and hinders the operation of the instruments.

When the first foot of earth is removed, they can dig and loosen the earth a foot deeper. But if those who remove the earth should with it take away the spades and pickaxes, the work will be equally obstructed as if they had left the loose earth unremoved.

I imagine the operation of fire upon fuel with the assistance of air may be in some degree similar to this. Fire penetrates bodies, and separates their parts; the air receives and carries off the parts separated, which if not carried off would impede the action of the fire. With this assistance therefore of a moderate current of air, the separation increases, but too violent a blast carries off the fire

itself; and thus any fire may be blown out, as a candle by the breath, if the blast be proportionable.

But if air contributed inflammatory matter, as some have thought, then it should seem, that the more air the more the flame would be augmented, which beyond certain bounds does not agree with the fact.

Some substances take fire, i. e. are kindled by the application of fire much sooner than others. This is in proportion as they are good or bad conductors of fire, and as their parts cohere with less or more strength A bad conductor of fire not easily permitting it to penetrate and be absorbed, and its force divided among the whole substance, its operation is so much the stronger on the surface to which it is applied, and is in a small depth of surface strong enough to produce the separation of parts which we call *burning*. All oils and fats, wax, sulphur, and most vegetable substances, are bad conductors of fire. The oil of a lamp, burning at the top, may be scarce warm at the bottom; a candle or a stick of wood inflamed at one end, is cool at the other. Metals, which are better conductors, are not so easily kindled, though, when sufficient fire is applied to them to separate their parts, they will all burn. But the fire applied to their surfaces enters more easily, is absorbed and divided; and not enough left on the surface to overcome the cohesion of their parts. A close contact with metals will for the same reason prevent

the burning of more inflammable substances. A flaxen thread, bound close round an iron poker, will not burn in the flame of a candle; for it must imbibe a certain quantity of fire before it can burn, i. e. before its parts can separate: but the poker, as fast as the fire arrives, takes it from the thread, conducts it away, and divides it in its own substance.

Common fire I conceive to be collected by friction from the common mass of that fluid, in the same manner as the electrical fluid is collected by friction, which I have endeavored to explain in some of my electrical papers, and, to avoid length in this letter, refer you to them. In wheels the particles of grease and oil acting as so many little rollers, and preventing friction between the wood and wood, do thereby prevent the collection of fire.

CURIOUS INSTANCE OF THE EFFECT OF OIL ON WATER.

TO DR. PRINGLE, LONDON.

SIR, *Philadelphia, Dec.* 1, 1762.

DURING our passage to Madeira, the weather being warm, and the cabin windows constantly open, for the benefit of the air, the candles at night flared and ran very much; which was an inconvenience. At Madeira we got oil to burn, and with a common glass tumbler or beaker, slung in

wire, and suspended to the cieling of the cabin, and a little wire hoop for the wick, furnished with corks to float on the oil, I made an Italian lamp, that gave us very good light all over the table.— The glass at bottom contained water to about one third of its height; another third was taken up with oil; the rest was left empty, that the sides of the glass might protect the flame from the wind. There is nothing remarkable in all this; but what follows is particular. At supper, looking on the lamp, I remarked, that though the surface of the oil was perfectly tranquil, and duly preserved its position and distance with regard to the brim of the glass, the water under the oil was in great commotion, rising and falling in irregular waves, which continued during the whole evening. The lamp was kept burning as a watch-light all night, till the oil was spent, and the water only remained. In the morning I observed, that though the motion of the ship continued the same, the water was now quiet, and its surface as tranquil as that of the oil had been the evening before. At night again, when oil was put upon it, the water resumed its irregular motions, rising in high waves almost to the surface of the oil, but without disturbing the smooth level of that surface. And this was repeated every day during the voyage.

Since my arrival in America, I have repeated the experiment frequently thus: I have put a pack-thread round a tumbler, with strings of the

same from each side, meeting above it in a knot at about a foot distance from the top of the tumbler. Then putting in as much water as would fill about one third part of the tumbler, I lifted it up by the knot, and swung it to and fro in the air; when the water appeared to keep its place in the tumbler as steadily as if it had been ice. But pouring gently in upon the water about as much oil, and then again swinging it in the air as before, the tranquillity before possessed by the water, was transferred to the surface of the oil, and the water under it was agitated with the same commotions as at sea.

I have shown this experiment to a number of ingenious persons. Those who are but slightly acquainted with the principles of hydrostatics, &c. are apt to fancy immediately that they understand it, and readily attempt to explain it; but their explanations have been different, and to me not very intelligible. Others, more deeply skilled in those principles, seem to wonder at it, and promise to consider it. And I think it is worth considering: for a new appearance, if it cannot be explained by our old principles, may afford us new ones, of use perhaps in explaining some other obscure parts of natural knowledge. I am, &c. B. FRANKLIN.

ON THE ELECTRICITY OF FOGS.

To Thomas Ronayne,—Cork.

London, April 20, 1766.

I received your very obliging and ingenious letter by Captain Kearney. Your observations on the Electricity of Fogs, and of the air in Ireland, and of the several circumstances attending a thunder-storm, are very curious; and I thank you for them. I have endeavored to get Father Beccaria's book for you, but find it is not to be had here: 'tis in 2 vols. 4to. in Italian, printed at Turin. In my opinion no part of the earth is, or can be, in a negative state of electricity naturally; and though an inequality may in some circumstances be occasioned, an equality would soon follow, from the extreme subtilty of the electric fluid, and the good conductors the moist earth is filled with. But yet I think when a highly-charged positive cloud comes near the earth, it repels and drives inward the natural quantity of electricity in the superficial parts, and in buildings, trees, &c. so as to bring them into a real negative state before it strikes. And I think the negative state you often find your balls in that hang to your apparatus, is not occasioned always by negative clouds, but often by positive clouds having passed over it, which, in passing, have repelled and driven out part of the natural quantity of electricity that was in the apparatus; so that when they are passed, the re-

mainder diffusing itself equally in the apparatus, the whole is in a negative state. If you have read my experiments in pursuance of those made by Mr. Canton (they are in vol. 40 of the Transactions), you will easily understand this. But you may readily make some experiments that will show it clearly. Make a common wine-glass warm by the fire, that it may keep quite dry for some time; set it on a table, and place on it Mr. Canton's little box, the balls hanging from the box a little beyond the edge of the table. Rub another warm wine-glass with a piece of black silk, or even a common silk handkerchief, so as to excite it. Then bring the glass over the box at the end farthest from the balls, at three or four inches' distance, and you will see the balls diverge, being then electrified positively by the natural quantity of electricity that was in the box, driven to that end by the repelling force of the atmosphere of the rubbed glass. Touch the box near the balls (the rubbed glass remaining as at first), and the balls will come together, your finger taking away the quantity driven to that end. Then withdraw finger and glass at the same time, and the quantity left in the box diffusing itself equally, the balls will diverge again and be negative. While in this state, rub your glass afresh, and pass it over the box without coming too near, and you will see, as you approach it, the balls first close; they are then in a natural state: as the glass comes nearer, they

open again; they are then positive. When the glass passes and begins to leave them, they close again, and are then in the natural state. When it has quite left them, they open again, and are then negative. The rubbed glass may represent a positively charged cloud, which you see is thus capable of producing all the changes in the apparatus without the necessity of supposing any negative cloud at all. But yet I am convinced there are negative clouds; because they will sometimes drink at and through the apparatus a large full bottle of positive electricity, of which the apparatus itself could not have received and retained the hundredth part. And, indeed, it is easy to conceive how a strongly charged large positive cloud may reduce smaller clouds to a negative state, as it passes over or near them, by driving their natural quantity out of them to their under side, whence it strikes into the earth, or to their farther end, whence it strikes into neighboring clouds; so that when the great cloud has passed or removed farther, they are left in a negative state, like the apparatus; they being, as well as it, often insulated bodies, not in contact with the earth or one another. And in the same manner it is equally easy to conceive how a large negative cloud may make others positive. The experiment you mention of filing the glass is similar to one I made in 1751, or 1752. I had supposed in my letter that the internal pores of glass were less than

those near the surface, and so denied a passage to the electric fluid. To try whether this was so in fact, I ground one of my phials on one side extremely thin, passing a good way beyond the middle of the thickness, and very near to the other side, as I found on breaking it after the experiment. It charged as well after grinding as before; which satisfied me that my hypothesis was in that particular wrong. It is hard to conceive where the additional quantity on the charged side of glass is deposited, there is so much of it. I send you my meteorological paper, which has lately been printed here in the Transactions, following a paper of Mr. Hamilton's on the same subject. I am, &c.

B. FRANKLIN.

CONJECTURE AS TO ELEPHANTS BEING NATIVES OF AMERICA.

TO MR. CROGHAN.

SIR, *London, Aug.* 5, 1767.

I return you many thanks for the box of elephants' tusks and grinders. They are extremely curious on many accounts; no living elephants having been seen in any part of America by any of the Europeans settled there, or remembered in any tradition of the Indians. It is also puzzling to conceive what should have brought so many of them to die on the same spot; and that no such remains should be found in any other part of the

continent, except in that very distant country Peru, from whence some grinders of the same kind formerly brought, are now in the museum of the Royal Society. The tusks agree with those of the African and Asiatic elephant, in being nearly of the same form and texture; and some of them, notwithstanding the length of time they must have lain, being still good ivory. But the grinders differ, being full of knobs, like the grinders of a carnivorous animal; when those of the elephant, who eats only vegetables, are almost smooth. But then we know of no other animal with tusks like an elephant, to whom such grinders might belong. It is remarkable, that elephants now inhabit naturally only hot countries where there is no winter, and yet these remains are found in a winter country; and it is no uncommon thing to find elephants' tusks in Siberia, in great quantities, when their rivers overflow, and wash away the earth, though Siberia is still more a wintery country than that on the Ohio; which looks as if the earth had anciently been in another position, and the climates differently placed from what they are at present. With great regard, I am, sir, your most obedient humble servant, B. FRANKLIN.

ON THE COLICA PICTORUM, AND PERNICIOUS USE OF LEAD IN DISTILLERIES.

TO DR. EVANS.

DEAR SIR, *London, Feb.* 20, 1768.

I wrote you a few lines by Capt. Falconer, and sent you Dr. Watson's new piece of Experiments in Inoculation, which I hope will be agreeable to you.

In yours of November 20, you mention the lead in the worms of stills as a probable cause of the dry belly-ache among punch-drinkers in our West Indies. I had before acquainted Dr. Baker with a fact of that kind, the general mischief done by the use of leaden worms, when rum-distilling was first practised in New England, which occasioned a severe law there against them; and he has mentioned it in the second part of his piece not yet published. I have long been of opinion, that that distemper proceeds always from a metallic cause only; observing that it affects, among tradesmen, those that use lead, however different their trades —as glaziers, letter-founders, plumbers, potters, white-lead makers, and painters: from the latter, it has been conjectured, it took its name *colica pictorum,* by the mistake of a letter, and not from its being the disease of Poictou; and although the worms of stills ought to be of pure tin, they are often made of pewter, which has a great mixture in it of lead.

The Boston people pretending to interfere with the manufactures of this country, make a great clamor here against America in general. I have therefore endeavored to palliate matters a little in several public papers. It would, as you justly observe, give less umbrage if we meddled only with such manufactures as England does not attend to. That of linen might be carried on more or less in every family, and silk, I think, in most of the colonies. But there are many manufactures that we cannot carry on to advantage, though we were at entire liberty. And after all, the true source of riches is husbandry. That is truly productive of new wealth; manufacturers only change forms, and whatever value they give to the materials they work upon, they at the same time consume an equal value in provisions, &c. So that riches are not increased by manufacturing; the only advantage is, that provisions in the shape of manufactures are more easily carried for sale to foreign markets. And where they cannot be easily carried to market, 'tis well to transform them for our own use as well as foreign sale. In families also, where the children and servants of families have some spare time, 'tis well to employ it in making something. I am, with thanks for your good wishes, dear sir, your's, &c. B. FRANKLIN.

ON CHIMNIES, &c.

To Lord Kaimes.

London, Feb. 28, 1768.

It gave me great pleasure to see my dear good friend's name at the foot of a letter I received the other day, having been often uneasy at his long silence, blaming myself as the cause by my own previous backwardness and want of punctuality as a correspondent. I now suppose, (as in this he mentions nothing of it,) that a long letter I wrote him about this time twelvemonth, on the subject of the disputes with America, did miscarry, or that his answer to that letter miscarried, as I have never heard from him since I wrote that letter.

I have long been of an opinion similar to that you express, and think happiness consists more in small conveniencies or pleasures that occur every day, than in great pieces of good fortune that happen but seldom to a man in the course of his life. Thus I reckon it among my felicities, that I can set my own razor, and shave myself perfectly well; in which I have a daily pleasure, and avoid the uneasiness one is sometimes obliged to suffer from the dirty fingers or bad breath of a slovenly barber.

I congratulate you on the purchase of a new house so much to your mind, and wish that you may long inhabit it with comfort. The inconvenience you mention of neighboring smoke coming

down the vents, is not owing to any bad construction of the vent down which it comes, and therefore not to be remedied by any change of form. It is merely the effect of a law of nature, whereby, whenever the outward air is warmer than the walls of the vent, the air included being by those walls made colder, and of course denser and heavier than an equal column of the outward air, descends into the room, and in descending draws other air into the vent above to supply its place; which, being in its turn cooled and condensed by the cooler walls of the vent descends also, and so a current downwards is continued during the continuance of such difference in temperament between the outward air and the walls of the vent. When this difference is destroyed, by the outward air growing cooler, and the walls growing warmer, the current downwards ceases; and when the outward air becomes still colder than the walls, the current changes and moves from below upwards, the warmer walls rarefying the air they include, and thereby making it so much lighter than a column of the outward air of equal height, that it is obliged to give way to the other's superior weight and rise, is succeeded by colder air, which being warmed and rarefied in its turn, rises also, and so the upward current is continued. In summer, when fires are not made in the chimnies, the current generally sets downward from nine or ten in the morning during all the heat of the day, till five or six in the afternoon,

then begins to hesitate, and afterwards to set upwards during the night, continuing till about nine in the morning, then hesitating for some time before it again sets downwards for the day. This is the general course, with some occasional variation of hours, according to the length of days or changes of weather. Now when the air of any vent is in this descending state, if the smoke issuing from a neighboring vent happens to be carried over it by the wind, part will be drawn in and brought down into the room. The proper remedy then is, to close the opening of the chimney in the room by a board so fitted that little or no air can pass, whereby the currents above-mentioned will be prevented. This board to remain during the summer, and when fires are not made in the chimney. Chimnies that have fires in them daily are not subject to this inconvenience, the walls of their vents being kept too warm to occasion any downward current during the hours between the going out of one fire and the kindling of another. And indeed, in summer, those vents that happen to go up close joined with the kitchen vent, are generally kept so warm by that as to be free from the downward current, and therefore free from what you call neighbor smoke.

The Philadelphia grate which you mention is a very good thing, if you could get one that is rightly made, and a workman skilful in putting them up. Those generally made and used here are much

hurt by fancied improvements in their construction, and I cannot recommend them. As fuel with you is cheap and plenty, a saving in it is scarce an object. The sliding plates (of which I sent a model to Sir Alex. Dick) are, in my opinion, the most convenient for your purpose, as they keep a room sufficiently warm, are simple machines, easily fixed, and their management easily conceived and understood by servants.

I shall leave Europe with much greater regret if I cannot first visit you and my other friends in Scotland. I promise myself this happiness, but am not yet clear that I shall have time for it. Your kind invitation is extremely obliging. With sincere esteem I am, my dear friend, yours most affectionately, B. F.

ON ASTRONOMICAL SUBJECTS, ELECTRICITY, &c.

To Mr. Winthorp.

Dear Sir, *London, July* 2, 1768.

You must needs think the time long that your instruments have been in hand. Sundry circumstances have occasioned the delay. Mr. Short, who undertook to make the telescope, was long in a bad state of health, and much in the country for the benefit of the air. He however at length finished the material parts that required his own hand, and waited only for something about the mounting that was to have been done by another

workman; when he was removed by death. I have put in my claim to the instrument, and shall obtain it from the executors as soon as his affairs can be settled. It is now become much more valuable than it would have been if he had lived, as he excelled all others in that branch. The price agreed for was 100*l.*

The equal altitudes and transit instrument was undertaken by Mr. Bird, who doing all his work with his own hands for the sake of greater truth and exactness, one must have patience that expects any thing from him. He is so singularly eminent in his way, that the commissioners of longitude have lately given him 500*l.* merely to discover and make public his method of dividing instruments. I send it you herewith. But what has made him longer in producing your instrument is, the great and hasty demand on him from France and Russia, and our society here for instruments to go to different parts of the world for observing the next transit of Venus; some to be used in Siberia, some for the observers that go to the South Seas, some for those that go to Hudson's Bay. These are now all completed and mostly gone, it being necessary on account of the distance, that they should go this year to be ready on the spot in time. And now he tells me he can finish yours, and that I shall have it next week. Possibly he may keep his word. But we are not to wonder if he does not.

Mr. Martin, when I called to see his panopticon, had not one ready; but was to let me know when he should have one to show me. I have not since heard from him, but will call again.

Mr. Maskelyne wishes much that some of the governments in North America would send an astronomer to Lake Superior to observe this transit. I know no one of them likely to have a spirit for such an undertaking, unless it be the Massachusetts, or that have a person and instruments suitable. He presents you one of his pamphlets, which I now send you, together with two letters from him to me, relating to that observation. If your health and strength were sufficient for such an expedition, I should be glad to hear you had undertaken it. Possibly you may have an *élève* that is capable. The fitting you out to observe the former transit, was a public act for the benefit of science, that did your province great honor.

We expect soon a new volume of the Transactions, in which your piece will be printed. I have not yet got the separate ones which I ordered.

It is perhaps not so extraordinary that unlearned men, such as commonly compose our church vestries, should not yet be acquainted with, and sensible of the benefit of metal conductors, in averting the stroke of lightning, and preserving our houses from its violent effects; or that they should be still prejudiced against the use of such conductors, when we see how long even philosophers,

men of extensive science and great ingenuity, can hold out against the evidence of new knowledge that does not square with their preconceptions, and how long men can retain a practice that is conformable to their prejudices, and expect a benefit from such practice, though constant experience shows its inutility. A late piece of the *Abbé Nollet*, printed last year in the Memoirs of the French Academy of Sciences, affords strong instances of this; for though the very relations he gives of the effects of lightning in several churches and other buildings, shows clearly that it was conducted from one part to another by wires, gildings, or other pieces of metal that were within, or connected with the building; yet in the same paper he objects to the providing metalline conductors *without the building*, as useless or dangerous. He cautions people not to ring the church bells during a thunder storm, lest the lightning in its way to the earth should be conducted down to them by the bell-ropes, which are but bad conductors; and yet is against fixing rods on the outside of the steeple, which are known to be much better conductors, and which it would certainly choose to pass in, rather than in dry hemp. And though for a thousand years past bells have been consecrated by priests of the Romish church, in expectation that the sound of such blessed bells would drive away those storms, and secure our buildings from the stroke of lightning; and during so long

a period it has not been found by experience that places within the reach of such blessed sound are safer than others where it is never heard; but that on the contrary, the lightning seems to strike steeples of choice, and that at the very time the bells are ringing; yet still they continue to bless the new bells and jangle the old ones whenever it thunders. One would think it was now time to try some other trick; and ours is recommended, (notwithstanding what this able philosopher says,) by more than twelve years' experience, wherein, among the great number of houses furnished with iron rods in North America, not one so guarded has been materially hurt with lightning, several have been evidently preserved by their means; while a number of houses, churches, barns, ships, &c. in different places, unprovided with rods, have been struck and greatly damaged, demolished or burnt. Probably the vestries of our English churches are not well acquainted with these facts; otherwise, since as Protestants, they have no faith in the blessing of bells, they would be less excusable in not providing this other security for their respective churches, (more exposed than common buildings by their greater height,) and for the good people that may happen to be assembled in them during a tempest.

I have nothing new in the philosophical way to communicate to you, unless what follows may be such. When I was last year in Germany, I

met with a glass, being a tube about eight inches long, half an inch in diameter, with a hollow ball of near an inch diameter at one end, and one of near an inch and a half at the other, hermetically sealed, and half filled with water. If one end is held in the hand, and the other a little elevated above the level, a constant succession of large bubbles proceeds from the end in the hand to the other hand, and make an appearance that puzzled me much, till I found that the space not filled with water was also free from air; and either filled with a subtil invisible vapor continually rising from the water, and extremely rarefiable by the least heat at one end, and condensable again by the least cold at the other; or it is the very fluid of fire itself, which parting from the hand, pervades the glass, and by its expansive force depresses the water till it can pass between it and the glass, and escape to the other end, where it gets through the glass again into the air. I am rather inclined to the first opinion, but doubtful between the two. An ingenious artist here, *Mr. Nairne*, has made a number of them from mine, and improved them; for his are much more sensible than those I brought from Germany. I bored a very small hole through the wainscot in the seat of my window, through which a little cold air constantly entered, while the air in the room was kept warmer by fires daily made in it, being winter time. I placed one of his glasses with the elevated end against this hole,

and the bubbles from the other end, which was in a warmer situation, were continually passing day and night, to the no small surprise of philosophical spectators. Each bubble discharged is larger than that from which it proceeds, and yet that is not diminished; and by adding itself to the bubble at the other end, that bubble is not increased, which seems very parodoxical. When the balls at each end are made large, and the connecting tube very small and bent at right angles, so that the balls, instead of being at the ends, may be brought on the side of the tube, and the tube is held so as that the balls are above it, the water will be depressed in that which is held in the hand, and rise in the other as a jet or fountain; when it is all in the other it begins to boil, as it were, by the vapor passing up through it; and the instant it begins to boil a sudden coldness is felt in the ball held; a curious experiment first observed and shown me by Mr. Nairne, similar to the old observation, I think of Aristotle, that the bottom of a boiling pot is not warm; and may help to explain that fact, if indeed it is a fact. When the water stands at an equal height in both these balls, and all is at rest, if you wet one of the balls by means of a feather dipped in spirit, though the spirit is of the same temperament as to heat and cold as the water in the glass, yet the cold occasioned by the evaporation of the spirit from the wetted ball will so condense the vapor

over the water contained in that ball, as that the water of the other ball will be pressed up into it, followed by a succession of bubbles, till the spirit is all dried away. I think the observations on these little instruments may suggest and be applied to some beneficial uses. It has been thought that water reduced to vapor by heat, was rarefied only 14,000 times, and on this principle our engines for raising water by fire are said to be constructed; but if the vapor so much rarefied from water is capable of being itself still farther rarefied to a boundless degree by the application of heat to the vessels, or parts of vessels, containing the vapor, (as at first it is applied to those containing the water,) perhaps a much greater power may be obtained with little additional expense. I think, too, that the power of easily moving water from one end to the other of a moveable beam, suspended in the middle by a small degree of heat, may be applied advantageously to some other mechanical purposes.

The magic square and circle, I am told, have occasioned a good deal of puzzling among the mathematicians here, but no one has desired me to show him my method of disposing the numbers. It seems they wish rather to investigate it themselves. When I have the pleasure of seeing you I will communicate it. With singular esteem and respect, I am, dear sir, your most obedient humble servant,

B. FRANKLIN.

ON THE FREE USE OF AIR.

To Mons. Dubourg.

London, July 28, 1768.

* * * I greatly approve the epithet which you give, in your letter of the 8th of June, to the new method of treating the small-pox, which you call the *tonic* or bracing method; I will take occasion, from it, to mention a practice to which I have accustomed myself. You know the cold bath has long been in vogue here as a tonic; but the shock of the cold water has always appeared to me, generally speaking, as too violent, and I have found it much more agreeable to my constitution to bathe in another element, I mean cold air. With this view I rise almost every morning, and sit in my chamber without any clothes whatever, half an hour or an hour, according to the season, either reading or writing. This practice is not in the least painful, but, on the contrary, agreeable; and if I return to bed afterwards, before I dress myself, as sometimes happens, I make a supplement to my night's rest of one or two hours of the most pleasing sleep that can be imagined. I find no ill consequences whatever resulting from it, and that at least it does not injure my health, if it does not in fact contribute much to its preservation. I shall therefore call it for the future a *bracing* or *tonic* bath. * * *

B. Franklin.

The Philosophical Survey of Ireland has this remarkable passage:—"Smith mentions a Dr. Lyne, of Cork, who for the last fifty years of his life never glazed a window in his house, four of which he had in his bed-chamber, two on each side his bed. It is remarkable, that during all that time, nobody died in the house, till he himself was carried off by the small-pox at the age of 85. After the windows were glazed by his son, death became a frequent visitor."

ON VENTILATION, &c.

Written by Mr. Small, the Surgeon, but containing Dr. Franklin's Observations on the subject.

I do not know that we have in any author particular and separate directions concerning the ventilating of hospitals, crowded rooms, or dwelling-houses; or the making of proper drains for carrying off stagnant or putrid water. The want of such general information on these subjects, has induced me to endeavor to recollect all I can of the many instructive conversations I have had upon these matters, with that judicious and most accurate observer of nature, Dr. Benjamin Franklin. I do this in hopes that either the Doctor himself or some other person well qualified for the task, may follow the example set in so masterly a manner by Sir John Pringle, Bart. when speaking on the preservation of the health of seamen.

It has long been observed, that if a number of persons are shut up in a small room, of which the internal air has little or no communication with

the external, the respiration of those who are so confined renders by degrees the air of that room effete, and unfit for the support of life.

Dr. Franklin was, if I mistake not, the first who observed that respiration communicated to the air a quality resembling the mephitic; such as the *Grotto del Cane* near Naples. The air impressed with this quality rises only to a certain height, beyond which it gradually loses it. The amendment begins in the upper part, and descends gradually until the whole becomes capable of sustaining life. The Doctor confirmed this by the following experiment. He breathed gently through a tube into a deep glass mug, so as to impregnate all the air in the mug with this quality. He then put a lighted *bougie* into the mug; and upon touching the air therein the flame was instantly extinguished; by frequently repeating this operation, the *bougie* gradually preserved its light longer in the mug, so as in a short time to retain it to the bottom of it; the air having totally lost the bad quality it had contracted from the breath blown into it.

At the same time that the lower part of the air is thus affected, an acrid noxious quality may be communicated to its upper part in the room, occasioned by the volatile putrescent effluvia of the persons enclosed therein. "It is surprising," says Sir John Pringle, in his observations on the Diseases of the Army, fourth edit. p. 109, "in how

few days the air will be corrupted in close and crowded wards; and what makes it hard to remedy the evil, is the difficulty of convincing either nurses or the sick themselves, of the necessity of opening the windows and doors at any time for a supply of fresh air."

It may be inferred from the above account of mephitic air, that such air can be but little altered by a ventilator in the ceiling of a room; and Dr. Franklin justly concluded, that in crowded rooms, and especially in bed-rooms in dwelling-houses, a current of air should be kept up in the lower part of the rooms, to carry off what is thus affected. He approved of the use of chimnies for this purpose, especially when the current is quickened by a fire. Even when there is not any fire in the chimney, a current of air is constantly kept up in it, by its ascending or descending in the flue, as the weight of the internal or external air preponderates. This creates a kind of tide in the flue, conducing much to the healthiness of air in rooms: and hence we may see the injudiciousness of having chimney boards which fit closely, and thereby prevent a salutary circulation in the air. Hence also in warm weather we may account for liquors or other things kept in a chimney being cooled, and more so if means are used to create an evaporation around them.

Every person has an atmosphere of his own, heated by the warmth of his body, which can be

dissipated only by motion in the circumambient air. Thus in warm weather wind cools the body, by carrying off the personal atmosphere, and promoting at the same time a more free evaporation of the effluvia arising from the body. This creates a great degree of coolness on the skin. The personal atmosphere can be but little affected by a ventilator in the ceiling of a room, unless the admission of external air is so directed as to act principally on the air surrounding those in the room. Dr. Franklin, when consulted on ventilating the House of Commons, represented that the personal atmosphere surrounding the members might be carried off by making outlets in the perpendicular parts of the seats, through which the air might be drawn off by ventilators, so placed, as to accomplish this without admitting any by the same channels. It will appear from what has been said, that windows placed high in the walls of churches or rooms intended for large assemblies, can contribute but little towards correcting the mephitic quality of the lower part of the air, or towards carrying off the personal atmospheres.

The experiments made for ventilating crowded rooms, by that most beneficent of men, the Rev. Dr. Stephen Hales, bring evident proof how much the upper part of the air in such places is vitiated by the volatile putrescent effluvia arising from the persons present in such rooms. He at the same

time showed an easy and effectual way to carry off such vitiated air. His ventilators were, however, attended with the inconveniency of occasioning smoky chimnies, by drawing off so much air, that there was not a sufficiency left to keep a current strong enough to carry the smoke up the chimney, unless a door or window was left open. The circulating ventilators in windows were intended for refreshing the air in rooms, without affecting the current of air up the chimney, but they did not affect the mephitic air, nor the higher air near the ceiling of lofty rooms, which is most vitiated with putrescent particles; and they were besides often out of repair.

Instead of either of these, Dr. Franklin proposed that openings should be made close to the ceilings of rooms communicating with a flue, which should ascend in the wall close to the flues of the chimnies, and where it can be done conveniently, close to the flue of the kitchen chimney; because the fire burning pretty constantly there, would keep the sides of that flue warmer than those of the other chimnies; whereby a quicker current of air would be kept up in the ventilating flue. Such a flue might be carried from the vaults or under ground offices. This would render them drier, without altering their temperature much as to heat or cold. These ventilating flues would cause a constant discharge of the volatile putrescent *effluvia* without interfering with the current of

air up the chimnies; while the current towards the chimney would carry off the *mephitic* air below. These ventilating flues would be peculiarly beneficial in bed-rooms of which the ceilings are low.

Dr. Franklin mentioned an instance of a number of Germans, who on their arrival in Pennsylvania were obliged to live in a large barn; there being at that time no other place of residence fit for them. Several small windows were made on both sides of the barn under the eaves. These windows were kept constantly open, even during a severe frost in the winter; and this without any detriment to the health of the Germans. Prejudice, said he, has raised so great a dread against cold air in England, that such openings would make every person shudder at the thought of being exposed to so great a degree of cold: and therefore I did not dare to recommend a practice, the good effects of which I had known. The dormitory for the youths of Westminster School is a similar instance; for the glass put in their high lofty windows is soon broken, but seldom repaired; yet without prejudice to the health of the youths.

There is a channel by which much of the vitiated air escapes, and is but little attended to. Whoever looks at the ceilings of rooms in old houses, will soon discover the traces of the rafters, by a difference in color, in parts of the ceiling, and deposits in it part of its contents, which discolors the intervals between the joists. In the British Museum

there is a remarkable instance of the inconveniency of the want of this outlet. The ceiling of one of the rooms in that house is covered with a picture, or painted cloth. The room continues warm with little fire; but the air soon affects the respiration of valetudinarians, as was often remarked by that accurate observer, Dr. G. Knight, late principal librarian.

An attentive observer will soon be convinced, that there is a current of warm air which ascends in the room from the chimney, while a fire burns. Dr. Franklin showed that this was the case, by the following experiment. He suspended by a thread, a piece of pasteboard cut in a spiral form. The thread was fastened to the chimney-piece, so that the pasteboard drawn out in a spiral form, came near to the edge of the chimney. The constant current of warm air, heated by the fire, gave a continued circular motion to the pasteboard. This warm air ascending to the ceiling, there spread, and kept a constant motion in the upper part of the air. The warm air thus ascending, coming into contact with the cool walls, and being thereby condensed, becomes heavier, and so falls along the sides of the walls. Also the glass in windows being exposed to the temperature of the external air, in cold weather, becomes colder than any other part of the room; therefore more sensibly descends, as may be seen by approaching a lighted *bougie* to a window. The flame is then

carried downwards by the air; or if the flame is extinguished, the smoke will more clearly shew this truth, by descending along the window till it meets the air of an equal temperature. This will be the case however tight the window; and the more so, the brighter and stronger the fire is, and the colder the external air; the circulation of the air being thereby quickened. This accounts for the familiar caution of avoiding to sit in or near a window. This circulation of the air is yet more evidently proved by the following instance: When there is a bright strong fire in a close room, open the door and present immediately a lighted candle to the upper part of the door-way, the flame will bend outward; though warm air in the higher part rushes out, lower the candle gradually, and the strength of the current outward will lessen by degrees, as the candle is lowered, till it comes to a space in which the flame shall rise upright: continue to lower the candle gradually, and then the current of cold air inward will gradually increase and more strongly bend the flame of the candle inward. This will be the case even in frosty and windy weather. May it not be inferred from this circumstance of so strong a current of air outwards in the upper part of the door-way, that an opening over or in the upper part of the door in the ward of an hospital might be of advantage, especially if there is no ventilating flue in the ceiling? By such means a circulation of the air

in the upper part of the ward could be constantly kept up; and thereby a vent would be given to the volatile putrescent particles. This vent might remain open at all times, without any prejudice to the patients.

What is said on this subject by Dr. John Armstrong, a gentleman no less remarkable for his benevolence than for his judgment and fine taste, may be properly mentioned here. "A constant circulation of fresh air is so necessary, so important in fevers, and in all feverish disorders, that it ought to be particularly considered in the construction of houses. It would be well, if in all the apartments of every house, but especially in bed-chambers, the upper sashes of every window were contrived to let down; for by this means the admission of fresh air would at all times be perfectly safe; except during a raw, damp, foggy night; as the body, even when under such a sweat as could not without danger be interrupted, may receive all the refreshing, restorative, and invigorating influence of the air, without being exposed to a stream of it; meantime, where this is wanting, the best method to supply it, is by drawing the bed-curtains close, now and then, for a few minutes at a time, while a free passage is made to the foul air, by opening the doors and windows." *Medical Essays, page* 22.

The noxious vapors that fill a sick room are not only offensive, but dangerous to those who con-

tinue in it for any time. If dangerous to people then in health, how detrimental must they be to one oppressed and struggling under an enfeebling disease! It is a common thing in a campaign to distribute the sick soldiers, ill of malignant fevers, in open barns, where the putrid volatile poison is in a short time dissipated.

There is, in a volume of the *Mémoires et Observations recueillies par la Société Economique de Berne*, a letter concerning the health of the inhabitants of the *Pays de Vaud*; part of which I beg to present here as bearing a near analogy to this subject. The letter is written by a most accurate and judicious clergyman. "One fact," says he, "deserves to be noticed. Taking one year with another, a greater proportional number always die in towns than in villages. But whence comes it, that when epidemic diseases prevail, the mortality takes quite a different road; that is, it is much more considerable in villages than in towns? I have taken great pains to find out the cause of this phenomenon, and am apt to impute the difference to the difference of habitations. The poor in cities and great towns dwell in houses originally not intended for them; but which being so old and past repairing, as to be no longer tenantable by persons at their ease, fall to the lot of the lower class of people. In these houses the rooms are spacious, cold as ice, where the air plays freely around, with doors and windows that do not half shut. The

inhabitants of these shattered houses are pitied; and yet the very circumstance of their being out of repair, is what contributes to the health of those who live in them, and facilitates their cure when diseases reign."

The more I see of hospitals, the more I am convinced of the great want of instructions on duly ventilating them. It is surprising to see what little attention has been paid in some hospitals about London to this article, which have been built since the importance of ventilation has been well known. In all of them there is too great a distance between the windows and the ceilings, where the volatile putrescent particles may remain till they become very acrid. With pleasure I here do justice to the judgment and precaution of Messrs. Adam, in the manner of ventilating the great room built by them for the meeting of the Society for the Encouragement of Arts, &c. by leaving spaces between the panes of glass in the sky-lights, the panes overlaying each other. These spaces being concealed from the eye, do not alarm those fearful of cold air, and keep the room constantly sweet.

The hospitals the most judiciously built in this respect, which I have seen, are those in Philadelphia and in Lyons. In the hospital in Philadelphia the wards are two stories high, with two rows of windows in each, the upper row being kept generally open: and the windows in the hospital

at Lyons are very lofty; so that the upper sashes may be for the most part kept open. Both hospitals are by this means perfectly sweet; so sweet, that a military gentleman, who went with me into the hospital at Lyons, and was unaccustomed to sick rooms, declared, that the air in the ward was not disagreeable to him, though it contained a considerable number of sick. Indeed they were kept very clean. I am sorry to say this is not the case in any one of our hospitals.

The naval hospital at Gibraltar is a square, which in a hot climate is itself a great imperfection, as the air within the square must in summer especially be greatly heated; and, as if they had studied to keep the cool air out of the wards, the windows open into the square only: whereas, if the west side had been left open, the wards might have received the cool breezes from the bay. The sick are lodged in long galleries not sufficiently divided to have the patients in separate wards, and no openings to carry off the putrid air lodged among the rafters which support the roof.

On my arrival in the island of Minorca, as surgeon to the royal artillery there, I was surprised at the neglect of my predecessors in that office, in regard to ventilating the hospital. There were no openings in the wards in which the sick lay, but the windows and doors, which were necessarily shut every night, to prevent the irregularities soldiers might be guilty of. Where chimnies had

been, they were built up to prevent the expense of fires: and thus during the night, the sick lay in an absolutely confined air. The consequence was, that when the nurse opened the wards in the morning, she was obliged to withdraw instantly; for the highly-infected air often brought on a vomiting. In this case I applied to our most worthy and ingenious chief engineer, the late Col. Mackellar, for leave to use such means as might create a circulation of air in all the wards. In this he readily concurred, and ordered the necessary alterations.

In each ward in which the flue of the chimney remained, an opening of about four or five inches square was made through the wall into the flue, as near the ceiling as possible. Round holes of about three inches diameter were cut low in each door, covered with a sliding flap to shut the holes occasionally: in some of the wards there never had been chimnies. In these, holes were cut through the wall close to the ceiling, which opened into a common passage: and when two such wards were contiguous, a hole was cut through the dividing wall as well as in the door of each ward. One of the wards in which there had not been a chimney, and which was arched with stones, was constantly so damp that no use was made of it. The walls and arch were covered with green moss. They were afterwards scraped to clear them of the moss which retained moisture, and then co-

vered with lime. This room became so dry, that though locked up for three months, during which I was confined with the gout, books and papers which had remained in it, were at the end of that time perfectly dry. The generally agreeable effects of this opening can scarcely be conceived: the wards, and indeed the whole hospital being rendered perfectly sweet, greatly to the benefit of the sick, as well as to the pleasure of the attendants.

The barracks in the square of the castle St. Philip, in which are lodged the detachment of the regiment of artillery doing duty there, are dry, except that being built of stone, they collect moisture on every sudden change of the air from cold to warm. Each barrack opens into the square, and is divided into three apartments. The part next the door has the whole height, and in it their arms and necessaries are kept. The inner part being about one-half, is divided into two floors. In the lower room they cook, each barrack having a mess or family in it, some of whom sleep in it. The fire, and the free access between it and the door, keep up a due circulation here. In the upper room most of the men sleep under a stone arch, the room being little more than six feet high in the centre, and therefore much lower in the sides. Under that arch from four to six or eight persons sleep, especially when there are children. This room is very stifling, there being little circu-

lation of air in it, more especially in calm warm weather, such as the nights generally are there in summer. In order to create a circulation of air in this upper room, openings were made into the flues of the chimnies of the lower room as near the centre of the arch as possible, the chimnies being in the corner of the rooms below. In general these openings drew very well, and gave great relief, especially to those who had weak or diseased lungs. The proper remedy here would have been to have had small flues made near the flues of the chimnies below, could it have been done. This measure is too much neglected in all barracks.

Whoever may on any future occasion have the direction of military hospitals, is already furnished with such judicious directions by my learned friends Sir John Pringle, Bart. and Dr. Donald Munro, that, were I to say any thing on that subject, I could only copy whole pages from them. Sir John Pringle's speech on giving the gold medal of the Royal Society to Captain Cook, in which he took occasion to point out the means of preserving the health of seamen, is equally deserving of commendation.

The healthiness of buildings does not perhaps depend more on the due ventilation of the rooms, than it does on the dryness of the situation, and of the foundation. Sir John Pringle, in the first part of his "*Observations on the Diseases of the*

Army," has given several instances of this truth. But as every man who regards his own life and health, or the lives and health of others, should be well acquainted with that work, I shall refer to the original. 'I have often lamented that the first part of that book, describing the natural consequences of the situation of places and their effects on health, has not been published separately; because it might thereby become of more general use to every man who leads a country life, or resorts thither frequently to enjoy quiet; for, being part of a book professedly treating of diseases, few think of consulting it, except those whose business it is to cure diseases.

However inviting the situation may be, and whatever may be the quality of the ground on which houses are built, generally drains should be made all round the house deeper than the foundation of the building, to carry off the superfluous moisture: even the moisture that may be lodged under ground; for it is essentially necessary that the lower part of the house be kept continually dry.

The advantages of drains or sewers are remarkably felt in London, which before the fire of London, was frequently afflicted with contagious malignant fevers. Before that period all the waste water and filth remained above ground; and the people, as Erasmus complained, were very inattentive to keeping their houses clean. The wooden

houses projected so much over the then very narrow streets, that the air became almost stagnant, and must have been loaded with putrid effluvia, there being very little circulation or current in the air thus confined to carry off these effluvia.

Before the city was rebuilt, that ingenious architect Sir Christopher Wren, planned and built the common sewers, as they continue to this day: and they are a lasting monument of his judgment and attention to the health and welfare of its inhabitants. These, together with the removal of signs and sign-posts, new paving and cleansing the streets, have been attended with such happy effects, that London and Westminster are now ranked among the most healthy spots in the island, for grown persons whose lungs can bear the cloud of smoke which generally hovers over them: and thus the apparent great calamity of a fire became a singular blessing to the city of London.

The quantity of water brought into the city by the New River and other water-works, which runs daily to waste, helps to cleanse and keep the common sewers sweet, and thereby contributes much to the healthiness of the city. Though foreign to the subject, it may be observed, that till the Restoration there were few gardens about London for supplying kitchen herbs. These became more numerous after that period, and still more so after the Revolution; a number of Dutch gardeners coming to England at that time. The

quantity of vegetables supplied by these gardens contribute greatly to the healthiness of the citizens.

Rome would not perhaps have become mistress of so extraordinary an empire, situated as that city is near marshy grounds, had not the common sewers, which still attract the admiration of all travellers, been so early and judiciously built by Tarquinius Priscus, who may for that reason be called a second founder of Rome. The ancient Romans were particularly attentive to the draining and cultivating of these marshes, and they soon became the granary of ancient Rome: but being neglected during the invasions of the barbarous nations, they are now the reproach and just chastisement of the supine indolence and inactivity of the modern Romans.

Gravel, which is generally reckoned a dry and healthy foundation to build upon, is found by experience not to deserve that character at all times, unless deep drains are made to carry off the water of heavy rains long continued: for by such rains the gravel may be so charged with water, especially in flat grounds, that the lower parts of the houses erected on such soils may prove damp. In all the flat grounds along the Thames the cellars are often filled with water after heavy rains; and if the water continues there stagnant, till the animal or vegetable substances mixed with it begin to putrify, aches, agues, and putrid fevers are the natural

consequences. Though Kensington palace stands high, and on a declivity, yet when King George the Second continued there till late in October, the lower parts of the house became damp, occasioned by the want of drains; and the servants became aguish. Stones which absorb and retain water, as the *Cantoon* stone in *Minorca* do, are in this respect similar to gravel. There was a remarkable instance of this in a magazine cut out of a solid rock of *Cantoon* stone in Georgetown, in Minorca. The magazine was covered with a well-limed arch and roof. Yet when the winter rains began to fall in November, the magazine was filled with water, as high as it was cut out of the rock. When drains were made to carry off the water, the magazine then became and continued to be sufficiently dry.

Might not low grounds on the banks of rivers, similar to those in Flanders, and so justly and judiciously complained of by Sir John Pringle, be rendered more healthy, by drains dug as deep as low-water mark in the adjacent rivers? Sluices might be made in the banks of the river, to prevent the tides or floods from entering into the drains. It would be advisable to cover the drains, to prevent the noxious vapors arising from putrid animal or vegetable substances, which generally rot in open ditches. The earth thrown out of the drains might serve to cover them, when the channels for carrying off the water are properly constructed. By

these means no surface would be lost for the growth of vegetables.

Willows, alders, and such trees as delight in a moist or wet soil, may be planted on the banks of ditches, if any such are permitted to remain open, that their leaves may correct the putrid vapors arising from the stagnant water in the ditches. I fear, however, that in the autumn, when the effects of putrid vapors are most severely felt, the leaves of these trees, being then hardened by age, may in a great measure lose the power of correcting the putrid vapors. The late summer shoots may afford aid till the equinoxial rains clear the ditches of all filth. That trees have not the power of proving an effectual remedy against these putrid exhalations, the frequency of agues in the low countries, in every such season, is a sufficient proof. If such trees grow on the banks of ditches, they should be kept in a pollard state, to admit of a free circulation of air.

An observation of Dr. Franklin's deserves a place here, especially as it is not generally attended to. The opinion is indeed against it. The banks of rivers which have a quick motion, and run on a clear sandy bottom, are very agreeable and healthy situations: but the sides of rivers which have oozy bottoms, or marshy banks, or which are in the neighborhood of extensive marshes, are to be avoided. When necessity or

any peculiar advantage obliges people to build near such bad neighbors, the south side, says the Doctor, is the most eligible; because the warm southerly winds, which promote a tendency to putrefaction, and are the most frequent, blow the noxious vapors from the buildings; whereas the northerly winds, which blow but seldom compared with the former, and which generally blow strongly, check putrefaction, and speedily carry off noxious vapors.

It is now well known that the stench arising from stationary privies, may be prevented by a cheap and easy method. The excrements may be received in tubs, so closely connected with the seat, that no air can pass. The lower ends of the tub should be sunk below the surface of water contained in proper cisterns. The excrements are soon dissolved in water, and so carried off, *every time the privy is washed, which should be as often as it is used.*

In towns the stench of the common sewers is sometimes very offensive. This may be prevented by interrupting the current of air through them by means of stink-traps; the construction and utility of which, are of late years well known in London. As sand or other filth may be apt to lodge in the deepened place, it should be so contrived, as to be easily come at, in order to clear away every obstruction.

Let me add here to the method of correcting bad

water, proposed by Dr. Munro, in his *Essay on the Means of preserving the Health of Soldiers*, the following easy method of keeping water clear and sweet, ascertained by several experiments, made some years ago by the Society for the Encouragement of Arts, &c. in London. The method is to mix clay with the water in such quantities, that when the clay is dissolved, the hand immersed under the surface of the water shall not be seen. The clay subsiding, carries down with it all the impurities, and, in a manner burying them, prevents their communicating any bad taste or smell to the water, which thereby continues long clear and sweet. Clay may probably correct stagnant water, and thereby preserve it clear and good in dry seasons, and may thus become very useful, where there is no running water. If any bad taste or smell remains after the use of the clay, it may be carried off by one of the ventilators recommended for that purpose by the Rev. Dr. Hales. The clear water may be drawn off by a siphon or a cock, placed high enough not to touch the clay.

A. S.

ON RAIN.

Extract of a Letter to Dr. Percival, 1771.

"On my return to London I found your favor of the 16th May, (1771.) I wish I could, as you desire, give you a better explanation of the pheno-

menon in question, since you seem not quite satisfied with your own; but I think we want more and a greater variety of experiments in different circumstances, to enable us to form a thoroughly satisfactory hypothesis. Not that I make the least doubt of the facts already related, as I know both Lord Charles Cavendish and Dr. Heberden to be very accurate experimenters: but I wish to know the event of the trials proposed in your six queries; and also, whether in the same place where the lower vessel receives nearly twice the quantity of water that is received by the upper, a third vessel placed at half the height will receive a quantity proportionable. I will, however, endeavor to explain to you what occurred to me, when I first heard of the fact.

I suppose it will be generally allowed, on a little consideration of the subject, that scarce any drop of water was, when it began to fall from the clouds, of a magnitude equal to that it has acquired when it arrives at the earth; the same of the several pieces of hail; because they are often so large and weighty, that we cannot conceive a possibility of their being suspended in the air, and remaining at rest there for any time, how small soever; nor do we conceive any means of forming them so large, before they set out to fall. It seems then, that each beginning drop, and particle of hail, receives continual addition in its progress downwards. This may be several ways: by the

union of numbers in their course, so that what was at first only a descending mist, becomes a shower; or by each particle in its descent through air that contains a great quantity of dissolved water, striking against, attaching to itself, and carrying down with it, such particles of that dissolved water as happen to be in its way; or attracting to itself such as do not lie directly in its course, by its different state with regard either to common or electric fire; or by all these causes united.

In the first place, by the uniting of numbers, larger drops might be made, but the quantity falling in the same space would be the same at all heights; unless, as you mention, the whole should be contracted in falling, the lines described by all the drops converging, so that what set out to fall from a cloud of many thousand acres, should reach the earth in perhaps a third of that extent, of which I somewhat doubt. In the other cases we have two experiments.

1. A dry glass bottle, filled with very cold water, in a warm day, will presently collect from the seemingly dry air that surrounds it, a quantity of water that shall cover its surface and run down its sides; which perhaps is done by the power wherewith the cold water attracts the fluid common fire, that had been united with the dissolved water in the air, and drawing that fire through the glass into itself, leaves the water on the outside.

2. An electrified body left in a room for some time, will be more covered with dust than other bodies in the same room not electrified; which dust seems to be attracted from the circumambient air.

Now we all know that rain, even in our hottest days, comes from a very cold region. Its falling sometimes in the form of ice shows this clearly; and perhaps even the rain is snow or ice when it first moves downwards, though thawed in falling: and we know that the drops of rain are often electrified. But those causes of addition to each drop of water, or piece of hail, one would think could not long continue to produce the same effect; since the air through which the drops must fall, must soon be stripped of its previously dissolved water, so as to be no longer capable of augmenting them. Indeed very heavy showers of either are never of long continuance, but moderate rains often continue so long as to puzzle this hypothesis: so that upon the whole I think, as I intimated before, that we are yet hardly ripe for making one.

REPORT ON LIGHTNING CONDUCTORS FOR THE POWDER MAGAZINES AT PURFLEET.

TO THE PRESIDENT AND COUNCIL OF THE ROYAL SOCIETY.

(Drawn up by B. Franklin, Aug. 21, 1772.)

GENTLEMEN,

The Society being consulted by the Board of

Ordnance, on the propriety of fixing conductors for securing the Powder Magazines at Purfleet from lightning, and, having thereupon done us the honor of appointing us a committee to consider the same and report our opinion, we have accordingly visited those buildings, and examined with care and attention their situation, construction, and circumstances, which we find as follows:—

They are five in number, each about 150 feet long, about 52 feet wide, built of brick, arched under the roof, which in one of them is slated with a coping of lead 22 inches wide on the ridge, from end to end; and the others, we were informed, are soon to be covered in the same manner. They stand parallel to each other, at about 57 feet distance, and are founded on a chalk rock about 100 feet from the river, which rises, in high tides, within a few inches of the level of the ground, its brackish water also soaking through to the wells that are dug near the buildings.

The barrels of powder, when the magazines are full, lie piled on each other up to the spring of the arches; and there are four copper hoops on each barrel, which, with a number of perpendicular iron bars (that come down through the arches to support a long grooved piece of timber, wherein the crane was usually moved and guided to any part where it was wanted), formed broken conductors, within the building, the more dangerous from their being incomplete; as the explosion from hoop to

hoop in the passage of lightning drawn down through the bars among the barrels, might easily happen to fire the powder contained in them: but the workmen were removing all those iron bars (by the advice of some members of the society who had been previously consulted); a measure we very much approve of.

On an elevated ground, nearly equal in height with the tops of the magazines, and 150 yards from them, is the house wherein the board usually meet: it is a lofty building, with a pointed hip roof, the copings of lead down to the gutters; whence leaden pipes descend at each end of the building, into the water of two wells 40 feet deep, for the purpose of conveying water forced up by engines to a cistern in the roof.

There is also a proof-house adjoining to the end of one of the magazines; and a clock-house at the distance of   feet from them, which has a weather-cock on an iron spindle, and probably some incomplete conductors within, such as the wire usually extending up from a clock to its hammer, the clock, pendulum, rod, &c.

The blowing-up of a magazine of gunpowder by lightning within a few years past at Brescia in Italy, which demolished a considerable part of the town with the loss of many lives, does in our opinion strongly urge the propriety of guarding such magazines from that kind of danger. And since it is now well known from many observations, that

metals have the property of conducting, and a method has been discovered of using that property for the security of buildings, by so disposing and fixing iron rods, as to receive and convey safely away such lightning as might otherwise have damaged them, which method has been practised near 20 years in many places, and attended with success in all the instances that have come to our knowledge, we cannot therefore but think it advisable to provide conductors of that kind for the magazines in question.

In common cases it has been judged sufficient, if the lower part of the conductor were sunk three or four feet into the ground till it came to moist earth; but this being a case of the greatest importance, we are of opinion that greater precaution should be taken. Therefore we would advise, that at each end of each magazine a well should be dug in or through the chalk, so deep as to have in it at least 4 feet of standing water. From the bottom of this water should rise a piece of leaden pipe to or near the surface of the ground, where it should be strongly joined to the end of an upright iron bar, an inch and a half in diameter, fastened to the wall by leaden straps, and extending ten feet above the ridge of the building, tapering from the ridge upwards to a sharp point; the upper 12 inches to be copper, the iron to be painted.

We mention lead for the under-ground part of the conductor, as less liable to rust in water and

moist places, in the form of a pipe, as giving greater stiffness for the substance; and iron for the part above ground, as stronger and less likely to be cut away. The pieces of which the bar may be composed should be screwed strongly into each other by a close joint, with a thin plate of lead between the shoulders, to make the joining or continuation of metal more perfect. Each rod, in passing above the ridge, should be strongly and closely connected by iron or lead, or both, with the leaden coping of the roof, whereby a communication of metal will be made between the two bars of each building, for a more free and easy conducting of the lightning into the earth.

We also advise, in consideration of the great length of the buildings, that two wells of the same depth with the others, should be dug within 12 feet of the doors of the two outside magazines; that is to say, one of them on the north side of the north building, the other on the south side of the south building; from the bottoms of which wells similar conductors should be carried up to the eaves, there joining well with a plate of lead extending on the roof up to the leaden coping of the ridge, the said plate of lead being of equal substance with that of the coping.

We are further of opinion, that it will be right to form a communication of lead from the top of the chimney of the proof-house to the lead on its ridge, and thence to the lead on the ridge of the corridor,

and thence to the iron conductor of the adjacent end of the magazine; and also to fix a conductor from the bottom of the weather-cock spindle of the clock-house down on the outside of that building into the moist earth.

As to the board-house, we think it already well furnished with conductors by the several leaden communications above mentioned, from the point of the roof down into the water, and that by its height and proximity it may be some security to the buildings below it: we therefore propose no other conductor for that building, and only advise erecting a pointed rod on the summit, similar to those before described, and communicating with those conductors.

To these directions we would add a caution, that in all future alterations or repairs of the buildings, special care be taken that the metalline communications are not cut off or removed.

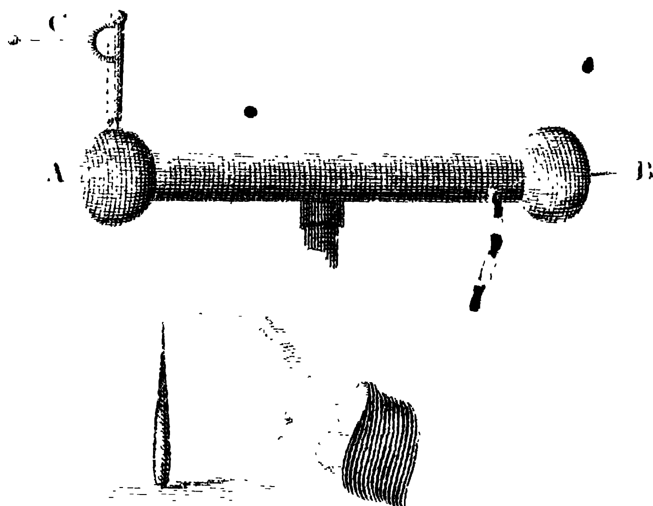
It remains that we express our acknowledgments to Sir Charles Frederick, surveyor-general of the ordnance, for the obliging attention with which he entertained and accommodated us on the day of our inquiry. With very great respect we are, gentlemen, your most obedient humble servants,

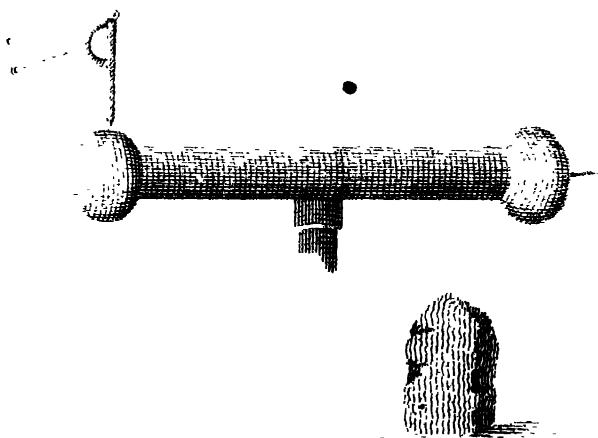


(Signed) H. CAVENDISH,
WILLIAM WATSON,
B. FRANKLIN,
J. ROBERTSON.

Aug. 21, 1772.

Plate II





EXPERIMENTS, OBSERVATIONS, AND FACTS RELATIVE TO THE UTILITY OF LONG POINTED RODS, FOR SECURING BUILDINGS FROM DAMAGE BY STROKES OF LIGHTNING.[1]

Aug. 27, 1772.

EXPERIMENT I.

THE prime conductor of an electric machine, A. B.[2] being supported about 10½ inches above the table by a wax-stand, and under it erected a *pointed wire* 7½ inches high, and ⅕ of an inch thick, tapering to a sharp point, and communicating with the table: when the *point* (being uppermost) is *covered* by the end of a finger, the conductor may be full charged, and the electrometer *c*[3] will rise to the height indicating a full charge: but the moment the point is *uncovered*, the ball of the electrometer drops, showing the prime conductor to be instantly discharged and nearly emptied of its electricity. Turn the wire, its *blunt* end upwards, (which represents an unpointed bar,) and no such effect follows, the electrometer remaining at its usual height when the prime conductor is charged.

Observation.—What quantity of lightning a high pointed rod well communicating with the earth may be expected to discharge from the clouds

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[1] Read at the committee appointed to consider the erecting conductors to secure the magazines at Purfleet. Aug. 27, 1772.

[2] See PLATE 2. [3] Mr. Henley's.

silently in a short time, is yet unknown; but I have reason, from a particular fact, to think it may at times be very great. In Philadelphia I had such a rod fixed to the top of my chimney, and extending about nine feet above it. From the foot of this rod, a wire (the thickness of a goose-quill) came through a covered glass tube in the roof, and down through the well of the staircase; the lower end connected with the iron spear of a pump. On the staircase opposite to my chamber-door, the wire was divided; the ends separated about six inches, a little bell on each end; and between the bells a little brass ball suspended by a silk thread, to play between and strike the bells when clouds passed with electricity in them. After having frequently drawn sparks and charged bottles from the bell of the upper wire, I was one night awaked by loud cracks on the staircase. Starting up and opening the door, I perceived that the brass ball, instead of vibrating as usual between the bells, was repelled and kept at a distance from both; while the fire passed sometimes in very large quick cracks from bell to bell, and somtimes in a continued dense white stream, seemingly as large as my finger; whereby the whole staircase was enlightened as with sun-shine, so that one might see to pick up a pin.[1] And from the apparent quantity thus dis-

[1] Mr. De Romas saw still greater quantities of lightning brought down by the wire of his kite. He had "explosions

charged, I cannot but conceive that a number[1] of such conductors must considerably lessen that of any approaching cloud, before it comes so near as to deliver its contents in a general stroke:—an effect not to be expected from bars unpointed, if the above experiment with the blunt end of the wire is deemed pertinent to the case.

EXPERIMENT II.

The pointed wire under the prime conductor continuing of the same height, *pinch* it between the thumb and finger near the top, so as *just to conceal* the point; then turning the globe, the electrometer will rise and mark the full charge. Slip the fingers down so as to discover about half an inch of the wire, then another half inch, and then another; at every one of these motions, *discovering more and more* of the pointed wire: you will see the elec-

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from it, the noise of which greatly resembled that of thunder, and were heard (from without) into the heart of the city, notwithstanding the various noises there. The fire seen at the instant of the explosion had the shape of a spindle eight inches long and five lines in diameter. Yet from the time of the explosion to the end of the experiment, no lightning was seen above, nor any thunder heard. At another time the streams of fire issuing from it were observed to be an inch thick and ten feet long."—*See Dr. Priestley's History of Electricity*, pages 354—6. *first edition.*

[1] Twelve were proposed on and near the magazines at Purfleet.

trometer fall quick and proportionably, stopping when you stop. If you slip down the *whole distance* at once, the ball falls instantly down to the stem.

Observation.—From this experiment it seems that a greater effect in drawing off the lightning from the clouds may be expected from *long* pointed rods, than from *short* ones; I mean from such as show the greatest length, *above the building* they are fixed on.

EXPERIMENT III.

Instead of pinching the point between the thumb and finger, as in the last experiment, keep the thumb and finger each at *near an inch distance* from it, but at the *same height*, the point between them. In this situation, though the point is fairly exposed to the prime conductor, it has little or no effect; the electrometer rises to the height of a full charge. But the moment the fingers are *taken away*, the ball falls quick to the stem.

Observation.—To explain this, it is supposed, that one reason of the sudden effect produced by a long naked pointed wire is, that (by the repulsive power of the positive charge in the prime conductor) the natural quantity of electricity contained in the pointed wire is driven down into the earth, and the point of the wire made strongly *negative*; whence it attracts the electricity of the prime conductor more strongly than bodies in their natural

state would do; the *small quantity of common matter* in the point, not being able by its attractive force to retain its *natural quantity of the electric fluid*, against the force of that repulsion. But the finger and thumb being substantial and blunt bodies, though as near the prime conductor, hold up better their *own* natural quantity against the force of that repulsion; and so, continuing nearly in the natural state, they jointly operate on the electric fluid in the point, opposing its descent, and *aiding the point* to retain it; contrary to the repelling power of the prime conductor, which would drive it down. And this may also serve to explain the different powers of the point in the preceding experiment, on the slipping down the finger and thumb to different distances.

Hence is collected, that a pointed rod erected *between two tall chimnies*, and very little higher, (an instance of which I have seen) cannot have so good an effect, as if it had been erected on one of the chimnies, its whole length above it.

EXPERIMENT IV.

If, *instead* of a long pointed wire, a *large solid body*, (to represent a building without a point) be brought under and as near the prime conductor, when charged; the ball of the electrometer will *fall* a little; and on taking away the large body, will *rise again*.

Observation.—Its *rising again* shows that the

prime conductor lost little or none of its electric charge, as it had done through the point: the *falling* of the ball while the large body was under the conductor, therefore shows that a quantity of its atmosphere was drawn from the end where the electrometer is placed to the part immediately over the large body, and there accumulated *ready* to strike into it with its whole undiminished force, as soon as within the striking distance; and, were the prime conductor moveable like a *cloud,* it would approach the body by attraction till within that distance. The swift motion of clouds, as driven by the winds, probably prevents this happening so often as otherwise it might do; for, though parts of the cloud may stoop towards a building as they pass, in consequence of such attraction, yet they are carried forward beyond the striking distance before they could by their descending come within it.

EXPERIMENT V.

Attach a small light *lock of cotton* to the under side of the prime conductor, so that it may hang down towards the pointed wire mentioned in the first experiment. *Cover* the point with your finger, and the globe being turned, the cotton will extend itself, stretching down towards the finger as at *a;* but on *uncovering* the point, it instantly flies up to the prime conductor, as at *b,* and continues there as long as the point is uncovered. The moment

you cover it again, the cotton flies down again, extending itself towards the finger; and the same happens in degree, if (instead of the finger) you use, uncovered, the *blunt* end of the wire uppermost.

Observation.—To explain this, it is supposed that the cotton, by its connection with the prime conductor, receives from it a quantity of its electricity; which occasions its being attracted by the *finger* that remains still in nearly its natural state. But when a *point* is opposed to the cotton, its electricity is thereby taken from it, faster than it can at a distance be supplied with a fresh quantity from the conductor. Therefore being reduced *nearer* to the natural state, it is attracted *up* to the electrified prime conductor, *rather than down*, as before, to the finger.

Supposing farther, that the prime conductor represents a cloud charged with the electric fluid; the cotton, a ragged fragment of cloud (of which the underside of great thunder-clouds are seen to have many); the finger, a chimney or highest part of a building; we then may conceive that when such a cloud passes over a *building*, some one of its ragged underhanging fragments may be drawn down by the chimney or other high part of the edifice; creating thereby a *more easy communication* between it and the great cloud.--But a *long pointed rod* being represented to this fragment, may occasion

its receding, like the cotton, up to the great cloud; and thereby *increase*, instead *of lessening* the distance, so as often to make it *greater* than the striking distance. Turning the *blunt end of a wire* uppermost, (which represents the unpointed bar) it appears that the same good effect is not from that to be expected. A long pointed rod, it is therefore imagined, may *prevent* some strokes; as well as *conduct* others that fall upon it, when a great body of cloud comes on so heavily that the above repelling operation on fragments cannot take place.

EXPERIMENT VI.

Opposite the side of the prime conductor place *separately*, isolated by wax stems, Mr. Canton's two boxes with pith balls suspended by fine linen threads. On each box lay a wire six inches long and $\frac{1}{5}$ of an inch thick, tapering to a sharp point; but so laid, as that four inches of the *pointed* end of *one* wire, and an equal length of the *blunt* end of the *other*, may project beyond the ends of the boxes; and both at 18 inches distance from the prime conductor. Then charging the prime conductor by a turn or two of the globe, the balls of each pair will separate; those of the box whence the point projects most, *considerably*; the others *less*. Touch the prime conductor, and those of the box with the *blunt* point will *collapse*, and join. Those connected with the *point* will at the same

time approach each other, *till* within about an inch, and *there remain.*

Observation.—This seems a proof, that though the small sharpened part of the wire must have had a *less natural* quantity in it before the operation, than the thick blunt part; yet a greater quantity was *driven down from it* to the balls. Thence it is again inferred that the pointed rod is rendered *more negative:* and farther, that if a *stroke must fall* from the cloud over a building, furnished with such a rod, it is more likely to be drawn to that pointed rod, than to a blunt one; as being more strongly negative, and of course its attraction stronger. And it seems more eligible, that the lightning should fall on the point of the conductor (provided to convey it into the earth), than on any other part of the building, *thence* to proceed to such conductor. Which end is also more likely to be obtained by the length and loftiness of the rod; as protecting more extensively the building under it.

It has been objected, that erecting pointed rods upon *edifices,* is to *invite* and draw the lightning into *them;* and therefore dangerous. Were such rods to be erected on buildings, *without continuing the communication* quite down into the moist earth, this objection might then have weight; but when such complete conductors are made, the lightning is invited not into the building, but into the *earth,*

the situation it aims at, and which it always seizes every help to obtain, even from broken partial metalline conductors.

It has also been suggested, that from such electric experiments *nothing certain can be concluded as to the great operations of nature;* since it is often seen that experiments, which have succeeded in small, in large have failed. It is true that in mechanics this has sometimes happened. But when it is considered that we owe our first knowledge of the nature and operations of lightning to observations on such small experiments; and that on carefully comparing the most accurate accounts of former facts, and the exactest relations of those that have occurred since, the effects have surprisingly agreed with the theory; it is humbly conceived that in natural philosophy, in this branch of it at least, the suggestion has not so much weight; and that the farther new experiments now adduced in recommendation of *long* sharp-pointed rods, may have some claim to credit and consideration.

It has been urged too, that though points may have considerable effects on a *small* prime conductor at *small distances,* yet on *great* clouds, and at *great distances,* nothing is to be expected from them. To this it is answered, that in those *small* experiments it is evident the points act at a greater than the *striking* distance; and in the large way, their

service is *only expected* where there is *such* nearness of the cloud as to *endanger a stroke;* and there, it cannot be doubted, the points must have some effect. And if the quantity discharged by a single pointed rod may be so considerable as I have shown it, the quantity discharged by a number, will be proportionably greater.

But this part of the theory does not depend alone on *small* experiments. Since the practice of erecting pointed rods in America, (now near 20 years[1]) five of them have been struck by lightning; viz. Mr. Raven's and Mr. Maine's in South Carolina; Mr. Tucker's in Virginia; Mr. West's and Mr. Moulder's in Philadelphia. Possibly there may have been more that have not come to my knowledge. But in every one of these, the lightning did *not* fall upon the *body of the house,* but precisely on the several *points* of the rods; and, though the conductors were sometimes *not sufficiently large and complete,* was conveyed into the earth, without any material damage to the buildings. Facts then *in great,* as far as we have them authenticated, justify the opinion that is drawn from the experiments *in small,* as above related.

It has also been objected, that unless we knew the quantity that might *possibly* be discharged at one stroke from the clouds, we cannot be sure we

[1] About the year 1752.

have provided *sufficient* conductors; and therefore cannot depend on their conveying away *all* that may fall on their points. Indeed we have nothing to form a judgment by in this case but past facts; and we know of no instance where a *complete* conductor to the moist earth *has* been insufficient, if half an inch diameter. It is probable that many strokes of lightning have been conveyed through the common leaden pipes affixed to houses to carry down the water from the roof to the ground: and there is no account of such pipes being melted and destroyed, as must sometimes have happened, if they had been insufficient. We can then only judge of the dimensions proper for a conductor of lightning, as we do of those proper for a *conductor of rain*, by past observation. And as we think a pipe of three inches' bore sufficient to carry off the rain that falls on a square of twenty feet, because we never saw such a pipe glutted by any shower; so we may judge a conductor of an inch diameter, more than sufficient for any stroke of lightning that will fall on its point. It is true that if another deluge should happen wherein the windows of heaven are to be opened, such pipes may be unequal to the falling quantity; and if God for our sins should think fit to rain fire upon us, as upon some cities of old, it is not expected that our conductors, of whatever size, should secure our houses against a miracle. Probably as water drawn up into the air, and

there forming clouds, is disposed to fall again in *rain* by its natural gravity, as soon as a number of particles sufficient to make a drop can get together; so when the clouds are (by whatever means) over or undercharged (with the *electric fluid*) to a degree sufficient to attract them towards the earth, the equilibrium is restored, before the difference becomes great beyond that degree. Mr. *Lane's electrometer*, for limiting precisely the quantity of a shock that is to be administered in a medical view, may serve to make this more easily intelligible. The discharging knob does by a screw approach the conductor to the distance intended, but there remains fixed. Whatever power there may be in a glass globe to collect the fulminating fluid, and whatever capacity of receiving and accumulating it there may be in the bottle or glass jar; yet neither the accumulation, or the discharge, ever exceeds the destined quantity. Thus, were the *clouds* always at a certain fixed distance from the earth, all discharges would be made when the quantity accumulated was equal to the distance. But there is a circumstance which, by occasionally lessening the distance, lessens the discharge; to wit, the moveableness of the clouds, and their being drawn nearer to the earth by attraction when electrified; so that discharges are thereby rendered more frequent and of course less violent. Hence whatever the quantity may be in nature, and whatever the power in the clouds of collecting it; yet

an accumulation and force beyond what mankind has hitherto been acquainted with, is scarce to be expected.[1] B. F.

ON THE SPOTS IN THE SUN: A NEW HYPOTHESIS.

To Mr. Humphry Marshall.

SIR, *London, Feb.* 14, 1773.

A CONSIDERABLE time after its arrival, I received the box of seeds you sent me the beginning of last year, with your observations on spots of the sun. The seeds I distributed among some of my friends who are curious: accept my thankful acknowledg-

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[1] It may be fit to mention here, that the immediate occasion of the dispute concerning the preference between pointed and blunt conductors of lightning, arose as follows:—A powder mill having blown up at Brescia, in consequence of its being struck with lightning, the English board of ordnance applied to their painter, Mr. Wilson, then of some note as an electrician, for a method to prevent the like accident to their magazines at Purfleet. Mr. Wilson having advised a blunt conductor, and it being understood that Dr. Franklin's opinion, formed upon the spot, was for a pointed one; the matter was referred in 1772 to the Royal Society, and by them, as usual, to a committee, who, after consultation, prescribed a method conformable to Dr. Franklin's theory. But a harmless stroke of lightning having, under particular circumstances, fallen upon one of the buildings and its apparatus, in May 1777, the subject came again into violent agitation, and was again referred to the society, and by the society again referred to a new committee, which committee confirmed the decision of the first committee.

ments for them. The observations I communicated to our astronomers of the Royal Society, who are much pleased with them, and hand them about from one to another; so that I have had little opportunity of examining them myself, they not being yet returned to me. Here are various opinions about the solar spots. Some think them vast clouds of smoke and soot arising from the consuming fuel on the surface, which at length take fire again on their edges, consuming and daily diminishing till they totally disappear. Others think them spots of the surface, in which the fire has been extinguished, and which by degrees is rekindled. It is however remarkable, that though large spots are seen gradually to become small ones, no one has observed a small spot gradually become a large one; at least I do not remember to have met with such an observation. If this be so, it should seem they are suddenly formed of their full size; and perhaps if there were more such constant and diligent observers as you, some might happen to be observing at the instant such a spot was formed, when the appearances might give some ground of conjecture by what means they were formed. The professor of astronomy at Glasgow, Dr. Wilson, has a new hypothesis. It is this: that the sun is a globe of solid matter, all combustible, perhaps, but whose surface only is actually on fire to a certain depth, and all below that depth unkindled,

like a log of wood, whose surface to half an inch deep may be burning coal, while all within remains wood. Then he supposes, by some explosion similar to our earthquakes, the burning part may be blown away from a particular district, leaving bare the unkindled part below, which then appears a spot, and only lessens as the fluid burning matter by degrees flows in upon it on all sides, and at last covers or rekindles it. He founds this opinion on certain appearances of the edges of the spots as they turn under the sun's disk, or emerge again on the other side: for if there are such hollows in the sun's face as he supposes, and the bright border round their edges be the fluid burning matter flowing down the banks into the hollow, it will follow, that while a spot is in the middle of the sun's disk, the eye looking directly upon the whole, may discern that border all round; but when the hollow is moved round to near the edge of the disk, then, though the eye which now views it aslant can see full the farthest bank, yet that which is nearest is hidden, and not to be distinguished; and when the same spot comes to emerge again on the other side of the sun, the bank which before was visible is now concealed, and that concealed which before was visible, gradually changing, however, till the spot reaches the middle of the disk, when the bank all round may be seen as before. Perhaps your telescope may be scarce strong enough to observe this. If it is,

I wish to know whether you find the same appearances. When your observations are returned to me, and I have considered them, I shall lodge them among the papers of the society, and let you know their sentiments. With great esteem and regard, I am, &c. B. FRANKLIN.

ON THE ANALOGY BETWEEN MAGNETISM AND ELECTRICITY.

TO MONSIEUR DUBOURG.

SIR, *London, March* 10, 1773.

As to the magnetism which seems produced by electricity, my real opinion is, that these two powers of nature have no affinity whatever with each other, and that the apparent production of magnetism is purely accidental. The matter may be explained thus:—

1st. The earth is a great magnet.

2dly. There is a subtile fluid, called the magnetic fluid, which exists in all ferruginous bodies, equally attracted by all their parts, and equally diffused through their whole substance; at least where the equilibrium is not disturbed by a power superior to the attraction of the iron.

3dly. This natural quantity of the magnetic fluid, which is contained in a given piece of iron, may be put in motion, so as to be more rarefied in one part, and more condensed in another; but it

cannot be withdrawn by any force that we are yet made acquainted with, so as to leave the whole in a negative state, at least relatively to its natural quantity; neither can it be introduced so as to put the iron into a positive state, or render it *plus*. In this respect, therefore, magnetism differs from electricity.

4thly. A piece of soft iron allows the magnetic fluid which it contains to be put in motion by a moderate force, so that being placed in a line with the magnetic pole of the earth, it immediately acquires the properties of a magnet; its magnetic fluid being drawn or forced from one extremity to the other; and this effect continues as long as it remains in the same position, one of its extremities becoming positively magnetised, and the other negatively. This temporary magnetism ceases as soon as the iron is turned east and west, the fluid immediately diffusing itself equally through the whole iron, as in its natural state.

5thly. The magnetic fluid in hard iron, or steel, is put in motion with more difficulty, requiring a force greater than the magnetism of the earth to excite it; and when once it has been forced from one extremity of the steel to the other, it is not easy for it to return; and thus a bar of steel is converted into a permanent magnetic.

6thly. A great heat, by expanding the substance of this steel, and increasing the distance between its particles, affords a passage to the electric fluid,

which is thus again restored to its proper equilibrium; the bar appearing no longer to possess magnetic virtue.

7thly. A bar of steel, which is not magnetic, being placed in the same position relatively to the pole of the earth which the magnetic needle assumes, and in this position being heated and suddenly cooled, becomes a permanent magnet. The reason is, that while the bar was hot, the magnetic fluid which it naturally contained, was easily forced from one extremity to the other by the magnetic virtue of the earth; and that the hardness and condensation produced by the sudden cooling of the bar, retained it in this state without permitting it to resume its original situation.

8thly. The violent vibrations of the particles of a steel bar, when forcibly struck in the same position, separate the particles in such a manner during their vibration, that they permit a portion of the magnetic fluid to pass, influenced by the natural magnetism of the earth; and it is afterwards so forcibly retained by the re-approach of the particles when the vibration ceases, that the bar becomes a permanent magnet.

9thly. An electric shock passing through a needle in a like position, and dilating it for an instant, renders it for the same reason a permanent magnet; that is, not by imparting magnetism to it, but by allowing its proper magnetic fluid to put itself in motion.

10thly. Thus there is not in reality more magnetism in a given piece of steel after it is become magnetic, than existed in it before. The natural quantity is only displaced or repelled.—Hence it follows that a strong apparatus of magnets may charge millions of bars of steel, without communicating to them any part of its proper magnetism; only putting in motion the magnetism which already existed in these bars.

I am chiefly indebted to that excellent philosopher of Petersburgh, M. Æpinus, for this hypothesis, which appears to me equally ingenious and solid. I say *chiefly*, because, as it is many years since I read his book, which I have left in America, it may happen, that I may have added to or altered it in some respect; and if I have misrepresented any thing, the error ought to be charged to my account.

If this hypothesis appears admissible, it will serve as an answer to the greater part of your questions.—I have only one remark to add, which is, that however great the force is of magnetism employed, you can only convert a given portion of steel into a magnet of a force proportioned to its capacity of retaining its magnetic fluid in the new position in which it is placed, without letting it return. Now this power is different in different kinds of steel, but limited in all kinds whatever.

B. FRANKLIN.

ON THE CHOICE OF GLASS FOR THE LEYDEN EXPERIMENT.

TO THE SAME.

SIR, *London, June* 1, 1773.

I WISH, with you, that some chemist (who should, if possible, be at the same time an electrician), would, in pursuance of the excellent hints contained in your letter, undertake to work upon glass with the view which you have recommended. By means of a perfect knowledge of this substance, with respect to its electrical qualities, we might proceed with more certainty, as well in making our own experiments, as in repeating those which have been made by others in different countries, which I believe have frequently been attended with different success on account of differences in the glass employed, thence occasioning frequent misunderstandings and contrariety of opinions.

There is another circumstance much to be desired with respect to glass, and that is, that it should not be subject to break when highly charged in the Leyden experiment. I have known eight jars broken out of twenty, and, at another time, twelve out of thirty-five. A similar loss would greatly discourage electricians desirous of accumulating a great power for certain experiments. — We have never been able hitherto to account for the cause of such misfortunes. The first idea which occurs is, that the positive electri-

city being accumulated on one side of the glass, rushes violently through it, in order to supply the deficiency on the other side, and to restore the equilibrium. This, however, I cannot conceive to be the true reason, when I consider that a great number of jars being united, so as to be charged and discharged at the same time, the breaking of a single jar will discharge the whole; for, if the accident proceeded from the weakness of the glass, it is not probable that eight of them should be precisely of the same degree of weakness, as to break every one at the same instant, it being more likely that the weakest should break first, and, by breaking, secure the rest; and again, when it is necessary to produce a certain effect, by means of the whole charge passing through a determined circle, (as, for instance, to melt a small wire,) if the charge, instead of passing in this circle, rushed through the sides of the jars, the intended effect would not be produced, which, however, is contrary to fact. For these reasons, I suspect, that there is, in the substance of the glass, either some little globules of air, or some portions of unvitrified sand or salt, into which a quantity of the electric fluid may be forced during the charge, and there retained till the general discharge; and that the force being suddenly withdrawn, the elasticity of the fluid acts upon the glass in which it was enclosed, not being able to escape hastily without breaking the glass. I offer

this only as a conjecture, which I leave to others to examine.

The globe which I had which could not be excited, though it was from the same glass-house which furnished the other excellent globes in my possession, was not of the same frit. The glass which was usually manufactured there, was rather of the green kind, and chiefly intended for drinking-glasses and bottles; but the proprietors being desirous of attempting a trial of white glass, the globe in question was from this frit. The glass not being of a perfect white, the proprietors were dissatisfied with it, and abandoned their project.—I suspected that too great a quantity of salt was admitted into the composition; but I am no judge of these matters.

B. FRANKLIN.

ON THE DEATH OF PERSONS STRUCK BY LIGHTNING.

TO THE SAME.

SIR,

YOUR observations on the causes of death, and the experiments which you propose for recalling to life those who appear to be killed by lightning, demonstrate equally your sagacity and your humanity. It appears, that the doctrines of life and death, in general, are yet but little understood.

A toad buried in sand will live, it is said, till the sand becomes petrified; and then, being enclosed in the stone, it may still live, for we know

not how many ages. The facts which are cited in support of this opinion are too numerous, and too circumstantial, not to deserve a certain degree of credit. As we are accustomed to see all the animals with which we are acquainted, eat and drink, it appears to us difficult to conceive how a toad can be supported in such a dungeon: but, if we reflect, that the necessity of nourishment which animals experience in their ordinary state, proceeds from the continual waste of their substance by perspiration, it will appear less incredible, that some animals in a torpid state, perspiring less because they use no exercise, should have less need of aliment; and that others, which are covered with scales or shells, which stop perspiration, such as land and sea turtles, serpents, and some species of fish, should be able to subsist a considerable time without any nourishment whatever. A plant, with its flowers, fades and dies immediately, if exposed to the air without having its root immersed in a humid soil, from which it may draw a sufficient quantity of moisture to supply that which exhales from its substance, and is carried off continually by the air. Perhaps, however, if it were buried in quicksilver, it might preserve for a considerable space of time its vegetable life, its smell and color. If this be the case, it might prove a commodious method of transporting from distant countries those delicate plants which are unable to sustain the inclemency of the weather at sea, and which require

particular care and attention.—I have seen an instance of common flies preserved in a manner somewhat similar. They had been drowned in Madeira wine, apparently about the time when it was bottled in Virginia, to be sent hither (to London). At the opening of one of the bottles, at the house of a friend where I then was, three drowned flies fell into the first glass which was filled. Having heard it remarked, that drowned flies were capable of being revived by the rays of the sun, I proposed making the experiment upon these: they were therefore exposed to the sun upon a sieve, which had been employed to strain them out of the wine. In less than three hours two of them began by degrees to recover life. They commenced by some convulsive motions in the thighs, and at length they raised themselves upon their legs, wiped their eyes with their fore-feet, beat and brushed their wings with their hind-feet, and soon after began to fly, finding themselves in Old England without knowing how they came thither. The third continued lifeless till sunset, when, losing all hopes of him, he was thrown away.

I wish it were possible, from this instance, to invent a method of embalming drowned persons, in such a manner that they might be recalled to life at any period, however distant; for, having a very ardent desire to see and observe the state of America an hundred years hence, I should prefer to any ordinary death, the being immersed in a

cask of Madeira wine, with a few friends, till that time, to be then recalled to life by the solar warmth of my dear country! But since in all probability we live in an age too early and too near the infancy of science, to hope to see such an art brought in our time to its perfection, I must for the present content myself with the treat which you are so kind as to promise me, of the resurrection of a fowl or a turkey-cock. I am, &c.

B. FRANKLIN.

ON THE MODE OF RENDERING MEAT TENDER BY ELECTRICITY.

TO MESSRS. DUBOURG AND D'ALIBARD.

MY DEAR FRIENDS,

MY answer to your questions concerning the mode of rendering meat tender by electricity, can only be founded upon conjecture; for I have not experiments enough to warrant the facts. All that I can say at present is, that I think electricity might be employed for this purpose; and I shall state what follows as the observations or reasons which make me presume so.

It has been observed that lightning, by rarefying and reducing into vapor the moisture contained in solid wood, in an oak, for instance, has forcibly separated its fibres, and broken it into small splinters; that by penetrating completely the hardest metals, as iron, it has separated the parts

in an instant, so as to convert a perfect solid into a state of fluidity: it is not then improbable, that the same subtile matter passing through the bodies of animals with rapidity, should possess sufficient force to produce an effect nearly similar.

The flesh of animals fresh killed in the usual manner is firm, hard, and not in a very eatable state, because the particles adhere too forcibly to each other. At a certain period the cohesion is weakened, and in its progress towards putrefaction, which tends to produce a total separation, the flesh becomes what we call tender, or is in that state most proper to be used as our food.

It has frequently been remarked, that animals killed by lightning putrefy immediately. This cannot be invariably the case, since a quantity of lightning sufficient to kill, may not be sufficient to tear and divide the fibres and particles of flesh, and reduce them to that tender state which is the prelude to putrefaction. Hence it is that some animals killed in this manner will keep longer than others. But the putrefaction sometimes proceeds with surprising celerity. A respectable person assured me that he once knew a remarkable instance of this. A whole flock of sheep in Scotland being closely assembled under a tree, were killed by a flash of lightning; and it being rather late in the evening, the proprietor, desirous of saving something, sent persons early the next morning to flay them; but the putrefaction was such, and the

stench so abominable, that they had not the courage to execute their orders, and the bodies were accordingly buried in their skins. It is not unreasonable to presume, that between the period of their death and that of their putrefaction, a time intervened in which the flesh might be only tender, and only sufficiently so to be served at table. Add to this, that persons who have eaten of fowls killed by our feeble imitation of lightning (electricity) and dressed immediately, have asserted that the flesh was remarkably tender.

The little utility of this practice has perhaps prevented its being much adopted. For though it sometimes happens that a company unexpectedly arriving at a country-house, or an unusual conflux of travellers in an inn, may render it necessary to kill a number of animals for immediate use; yet as travellers have commonly a good appetite, little attention has been paid to the trifling inconvenience of having their meat a little tough. As this kind of death is nevertheless more sudden, and consequently less severe than any other, if this should operate as a motive with compassionate persons to employ it for animals sacrificed for their use, they may conduct the process thus:—

Having prepared a battery of six large glass jars, (each from 20 to 24 pints,) as for the Leyden experiment, and having established a communication, as usual, from the interior surface of each with the prime conductor; and having given them

a full charge, (which with a good machine may be executed in a few minutes, and may be estimated by an electrometer,) a chain which communicates with the exterior of the jars must be wrapped round the thighs of the fowl; after which the operator, holding it by the wings turned back, and made to touch behind, must raise it so high that the head may receive the first shock from the prime conductor. The animal dies instantly. Let the head be immediately cut off to make it bleed, when it may be plucked and dressed immediately. This quantity of electricity is supposed sufficient for a turkey of ten pounds weight, and perhaps for a lamb. Experience alone will inform us of the requisite proportions for animals of different forms and ages. Probably not less will be required to render a small bird which is very old tender, than for a larger one which is young. It is easy to furnish the requisite quantity of electricity, by employing a greater or less number of jars. As six jars, however, discharged at once, are capable of giving a very violent shock, the operator must be very circumspect, lest he should happen to make the experiment on his own flesh, instead of that of the fowl.

B. FRANKLIN.

ON THE NATURE OF SEA-COAL.

To Mons. Dubourg.

I am persuaded as well as you, that the sea-coal has a vegetable origin, and that it has been formed near the surface of the earth; but as preceding convulsions of nature had served to bury it very deep in many places, and covered with many different strata, we are indebted to subsequent convulsions for having brought within our view the extremities of its veins, so as to lead us to penetrate the earth in search of it. I visited last summer a large coal-mine at Whitehaven in Cumberland; and in following the vein, and descending by degrees towards the sea, I penetrated below the ocean, where the level of its surface was more than 800 fathom above my head; and the miners assured me that their works extended some miles beyond the place where I then was, continually and gradually descending under the sea. The slate which forms the roof of this coal-mine is impressed in many places with the figures of leaves and branches of fearn, which undoubtedly grew at the surface, when the slate was in the state of sand on the banks of the sea. Thus it appears that this vein of coal has suffered a prodigious settlement.

B. F.

ANSWER TO SOME INQUIRIES RESPECTING THE ART OF SWIMMING.

To the Same.

I am apprehensive that I shall not be able to find leisure for making all the disquisitions and experiments which would be desirable on this subject. I must therefore content myself with a few remarks.

The specific gravity of some human bodies, in comparison with that of water, has been examined by Mr. Robertson, in our Philosophical Transactions, vol. 50, page 30, for the year 1757.—He asserts that fat persons with small bones float most easily upon water.

The diving bell is also accurately described in our Transactions.

When a youth, I made two oval pallets, each about ten inches long, and six broad, with a hole for the thumb, in order to retain it fast in the palm of my hand. They much resembled a painter's pallets. In swimming I pushed the edges of these forward, and I struck the water with their flat surfaces as I drew them back. I remember I swam faster by means of these pallets, but they fatigued my wrists. I also fitted to the soles of my feet a kind of sandals, but I was not satisfied with them, because I observed that the stroke is partly given by the inside of the feet and the ancles, and not entirely with the soles of the feet.

We have here waistcoats for swimmers, which are made of double sail-cloth, with small pieces of cork quilted in between them.

I know nothing of the *scaphandre* of M. de la Chapelle.

I know by experience that it is a great comfort to a swimmer, who has a considerable distance to go, to turn himself sometimes on his back, and to vary in other respects the means of procuring a progressive motion.

When he is seized with the cramp in the leg, the method of driving it away is to give to the parts affected a sudden and vigorous and violent shock, which he may do in the air as he swims on his back.

During the great heats of summer there is no danger in bathing, however warm we may be, in rivers which have been thoroughly warmed by the sun. But to throw one-self into cold spring water when the body has been heated by exercise in the sun, is an imprudence which may prove fatal. I once knew an instance of four young men, who having worked at harvest in the heat of the day, with a view of refreshing themselves plunged into a spring of cold water; two died upon the spot, a third the next morning, and the fourth recovered with great difficulty. A copious draught of cold water, in similar circumstances, is frequently attended with the same effect in North America.

The exercise of swimming is one of the most healthy and agreeable in the world. After having swam for an hour or two in the evening, one sleeps coolly the whole night, even during the most ardent heats of summer. Perhaps the pores being cleansed, the insensible perspiration increases and occasions this coolness. It is certain that much swimming is a means of stopping a diarrhœa, and even of producing a constipation. With respect to those who do not know how to swim, or who are affected with a diarrhœa at a season which does not permit them to use that exercise, a warm bath, by cleansing and purifying the skin is found very salutary, and often effects a radical cure. I speak from my own experience frequently repeated, and that of others to whom I have recommended this.

You will not be displeased if I conclude these hasty remarks by informing you, that as the ordinary method of swimming is reduced to the act of rowing with the arms and legs, and is consequently a laborious and fatiguing operation when the space of water to be crossed is considerable; there is a method in which a swimmer may pass to great distances with much facility, by means of a sail: —this discovery I fortunately made by accident, and in the following manner:—

When I was a boy, I amused myself one day with flying a paper kite; and approaching the bank of a pond which was near a mile broad, the

weather being very warm, I tied the string to a stake, and the kite ascended to a very considerable height above the pond, while I was swimming. In a little time, being desirous of amusing myself with my kite, and enjoying at the same time the pleasure of swimming, I returned; and loosing from the stake the string with the little stick that was fastened to it, I went again into the water, where I found that lying on my back and holding the stick in my hands, I was drawn along the surface of the water in a very agreeable manner. Having then engaged another boy to carry my clothes round the pond to a place which I pointed out to him on the other side, I began to cross the pond with my kite, which carried me quite over without the least fatigue, and with the greatest pleasure imaginable. I was only obliged occasionally to halt a little in my course, and resist its progress, when it appeared that by following too quick I lowered the kite too much; by doing which occasionally, I made it rise again. I have never since that time practised this singular mode of swimming, though I think it not impossible to cross in this manner from Dover to Calais.—The packet boat, however, is still preferable. Yours,

B. FRANKLIN.

STOVES FOR PUBLIC BUILDINGS.

Extract from a Letter to Dr. Cooper.

London, July 7, 1773.

"I CONGRATULATE you on the finishing of your new meeting-house. I have considered as well as I can, without being on the spot, the intention of warming it by some machine in the cold damp seasons. It must be a matter of difficulty to warm sensibly all the air in so large and so lofty a room, especially if the fire is not kept up in it constantly on the week days as well as Sundays. For though the machine is very large and made very hot, yet the space of air and quantity of wall to be warmed is so great, that it must be long before any considerable effect will be produced. Then it will descend by the walls and windows, which being very cold by the preceding week's absence of fire, will cool that descending air so much in so long a descent, that it will fall very heavily and uncomfortably upon the heads of all that happened to sit under it, and will proceed in cold currents along the floor to the warming machine wherever it is situated. This must continue till the walls are warmed, for which I think one day is by no means sufficient, and that therefore a fire kindled in the morning of the Sabbath will afford no comfort to the congregation that day, except to a few that sit near it, and some inconvenience to the rest from the currents above-mentioned. If, how-

ever, your people, as they are rich, can afford it, and may be willing to indulge themselves, should choose to keep up a constant fire in the winter months, you may have from this country a machine for the purpose, cast from the same patterns with those now used at the Bank, or that in Lincoln's Inn Hall, which are placed in the middle of the respective rooms. The smoke of these descends, and passing underground, rises in some chimney at a distance. Yours must be a chimney built, I suppose, without the house; and as it ought to draw well to prevent your being troubled with smoke (as they often are at the Bank), it should be on the south side; but this I fear would disfigure your front. That at Lincoln's Inn Hall draws better. They are in the form of temples, cast in iron, with columns, cornices, and every member of elegant architecture. And I mention casting them from the same patterns or moulds, because those being already made, a great deal of work and expense will thereby be saved. But if you can cast them in New England, a large vase, or an antique altar, which are more simple forms, may answer the purpose as well, and be more easily executed. Yet after all, when I consider the little effect I have observed from these machines in those great rooms, the complaints of people who have tried Buzaglo's stoves in halls, and how far your meeting-house must exceed them in all its dimensions, I apprehend, that after

a great deal of expense, and a good deal of dust on the seats and in the pews, which they constantly occasion, you will not find your expectations answered. And persuaded as I am, from philosophic considerations, that *no one ever* catches the disorder we call a cold from cold air, and therefore never at meeting, I should think it rather advisable to those who cannot well bear it, to guard against the short inconvenience of cold feet, (which only takes place towards the end of the service,) by basses or bear-skin cases to put the legs in, or by small stoves with a few coals under foot, *more majorum*.

PREPARATORY NOTES AND HINTS FOR WRITING A PAPER CONCERNING WHAT IS CALLED CATCHING OF COLD.

DEFINITION OF A COLD.

It is a siziness and thickness of the blood, whereby the smaller vessels are obstructed, and the perspirable matter retained, which being retained offends both by its quantity and quality; by quantity, as it outfills the vessels, and by its quality, as part of it is acrid, and being retained, produces coughs and sneezing by irritation.

HOW THIS SIZINESS IS PRODUCED.

1. By being long exposed in a cold air, without exercise: cold thickens glue.

2. By a diminished perspiration, either (1) from breathing and living in moist air, or (2) from the clogging of the pores by clammy sweat dried on and fastening down the scales of the skin; or (3) by cold constringing the pores, partially or totally, sleeping or waking; or (4) by having eat food of too gross particles for free perspiration, as oysters, pork, ducks, &c. People are found frequently costive after much bathing.

3. By repletion, as when more is thrown into the habit by eating and drinking than common perspiration is capable of discharging in due time; whence the vessels are distended beyond their spring, and the quantity of contained fluid, that should be briskly moved to preserve or acquire a due thinness, is too weighty for their force, whence a slow motion,—thence viscidity. This repletion so increased by a constipation of the belly happening at the same time. In an approaching cold, more water is made than usual.

4. By cooling suddenly in the air after exercise. Exercise quickening the circulation, produces more perspirable matter in a given time, than is produced in rest. And though more is likewise usually discharged during exercise, yet on sudden quitting of exercise, and standing in the air, the circulation and production of perspirable matter still continuing some time, the over quantity is retained. It is safer not to go into water too cold.

5. By particular effluvia in the air, from some unknown cause. General colds throughout a country. By being in a coach close, or small room with a person having a cold.

6. By relaxation of the solids, from a warm and moist air, so that they are too weak to give due motion to the fluids.

Of partial colds affecting parts only of the body.

Causes of feverishness attending colds.

Ill consequences often attending colds, as pleurisies, consumptions, &c. Some never taking cold, some frequently; cause of the difference.

Present remedies for a cold, should be warming, diluting, bracing.

Means of preventing cold; temperance, choice of meats and drinks, warm rooms, and lodging and clothing in winter; dry air, care to keep the belly open, and frequent discharge of water; warm bathing to cleanse the skin: rubbing after sweat, especially in the spring.

Difficulties that first put me on thinking on this subject. People get cold by less, and not by more, viz.

By putting on a damp shirt on a dry body—Yes.

By putting on a dry shirt on a wet body, though this wets the shirt ten times more—No.

By sitting in a room, where the floor has been newly washed—Yes.

By going into a river, and staying there an hour (no sheets so wet)—No.

By wetting the feet only—Yes.

By wetting all the clothes through to the body, and wearing them a whole day—No.

By sitting in a room against a crevice—Yes.

By sitting as long in the open air—No.

Few of these effects take place, if the vessels are kept empty.

Reapers in Pennsylvania:

Drinking cold water when they are hot.

If it makes them sweat, they are safe,

If not they fall ill, and some die.

People hot, should drink by spoonfuls: the reason.

Taking cold. The disorder only called so in English, and in no other language.

American Indians, in the woods, and the whites in imitation of them, lie with their feet to the fire in frosty nights, and *take no cold* while they can keep their feet warm.

Feet and hands apt to be cold in that disorder, and why. Is it the siziness, or the greater evaporation?

Hottentots grease themselves,—occasions other evacuations more plentiful. Greasing keeps the body warm. Bad to hold the water too long. Parts colder when first unclothed than afterwards, why?

It was a disgrace among the ancient Persians to cough or spit.

Probably as it argued intemperance.

Vessels when too full, leak. Quicksilver through leather. Thin fluid leaked evaporates. Corners of eyes, &c. Sizy will not all evaporate. What is left corrupts. Hence consumptions. Hectic fevers, from absorption of putrid pus. It ferments the blood like yeast.

People seldom get cold at sea, though they sleep in wet clothes. Constant exercise, moderate living. Bad cooks. Yet air is very moist. Wet floors. Sea surrounding, &c.

Exercise cures a cold. Bishop Williams riding several times from London or Exeter, to Salisbury.

Bark good for a cold taken early.

Particular parts more accustomed to discharge the irritating perspirable matter, as under the arms in some, feet in others, &c.

Experiment of two razors.

Every pain or disorder now ascribed to a cold.

It is the covering excuse of all intemperance.

Numbers of people in a close room, and exercising there, fill the air with putrid particles.

People killed by House of Commons, breathing the air through holes in ceiling.

Think they get cold by coming *out* of such hot rooms; they get them by being *in*.

Those who live in hotter rooms (stoves) get no colds;

Germans and all the northern people.

Alderman and turtle.

People remark they were very well before a cold, and eat hearty. Wonder how they catched it.

Signs of Temperance.

Mouth not clammy after sleep.
Saliva thin and watery.
Eyelids not stuck together with hard glue.
Voice clear.
No phlegm to raise.

Advice for mode of general temperance without appearing too singular.

Supper not bad after preparatory light dinner.

May be rectified by slight breakfast next morning.

He must be too full that one excess will much disorder.

Time of great meal mended of late.

One hour variation of compass in twenty years.

After dinner not fit for business.

People from the country get cold when they come to London, and why? Full living with moist air. London air generally moist, why? Much putrid air in London. Silver, &c.

Cooks and doctors should change maxims.

Common sense more common among the common Scotch.

Those who do not compare, cannot conceive the

difference between themselves and themselves in full or spare living.

Wet newspapers, why give colds.

Old libraries, and damp old books.

Putrid animal matter in paper size.

Courts should not sit after dinner.

Juries fast, a good institution.

Chess—Impatience of deliberation because more difficult. Writing, &c.

Most follies arise from full feeding. Reasons *pro* and *con* not all present.

Temperate nations wisest.

Dining entertainments bad.

Remains of barbarism—expensive.

Full feeding of children stupifies.

Fasting strengthens reason rather than subdues passion.

People often do not get cold when they think they do, and do when they think they do not.

Causes of colds are primary and secondary.

Colds are of different kinds, putrid and plethoric.

Scarce any air abroad so unwholesome as air in a close room often breathed.

Warm air dissolves more moisture than cold.

In hot countries men wrap themselves in wet sheets to sleep.

A general service to redeem people from the slavish fear of getting cold, by showing them where the danger is not, and that where it is, 'tis in their power to avoid it.

Surfeit, an expression formerly used, now laid aside.

Costiveness occasioning colds, how to be prevented.

Colds formerly called rheums and catarrhs.

Particular foods said to engender rheums.

Quere. Is Mr. Wood more or less subject to catch cold since he betook himself to his low diet?

Answer (by Mr. Wood). He now finds himself *much more* healthy, and *much less* liable to catch cold. What few colds he now catches are so very slight that he is not sensible of them, but from the urine, which is then not so clear.

I caused the above question to be asked Mr. Wood, and obtained the answer. It is the Mr. Wood who lives upon a pound of flour in a pudding.

B. FRANKLIN.

Dampier, speaking of the customs of the people at Mindanoo, p. 330, says,

"You see abundance of people in the river from morning to night washing their bodies or clothes: they strip and stand naked till they have done; then put them on and march out again."

Dr. Gregory says,

All that class of diseases which arise from catching cold, is found only among the civilised part of mankind. An old Roman or an Indian, in the pursuit of war or hunting, would plunge

into a river whilst in a profuse sweat, without fear, and without danger. The greater care we take to prevent catching cold, by the various contrivances of modern luxury, the more we become subject to it. We can guard against cold only by rendering ourselves superior to its influence. There is a striking instance of this in the vigorous constitutions of children who go thinly clad in all seasons and weathers.

The coats of the vessels are a kind of network which contains the fluids only when not so pressed as to enlarge the pores of the net, or when the fluids are not so pressed as to break the cohesion of the globules or particles, so as to make them small enough to come through. When the vessels are full, occasioned by a course of full living, they labor in carrying on the circulation; their spring or power of contraction and compressing the fluids they contain, being overstrained, is weakened, the circulation proceeds more slowly, the fluids thicken and become more gluey, both for want of due churning and because less heat is produced in the body. Such a body requires more aid of clothing and fire to preserve its warmth.

If a person in that state of body walks a mile or two, or uses any other exercise that warms him, the fluids are rarefied by the heat, distend the vessels still more, and the thinner parts of the fluids

in tender places force out through the pores of the vessels in form of a gluey water, viz. at the eyes, within the nose, and within the lungs. This in moderate exercise.

If the exercise is increased it comes through every pore in the skin, and is called sweat.

The more volatile parts of this extravasated fluid evaporate, and fly off in the air; the gluey part remains, thickens and hardens more or less, as it becomes more or less dry; in the nose and on the lungs where air is continually coming and going, it soon becomes a mucus, but can hardly grow drier because surrounded with moist parts and supplied with more moisture. What oozes out of the corner of the eye when shut, as in sleep, hardens into what is called a kind of gum, being in fact dry glue.

This in a morning almost sticks the eyelids together.

With such mucous matter the nose is sometimes almost stopped, and must be cleared by strong blowing.

In the wind-pipe and on the lungs it gathers and is impacted, so as sometimes to induce a continual coughing and hawking to discharge it.

If not easily discharged, but remaining long adhering to the lungs, it corrupts and inflames the parts it is in contact with; even behind the ears and between the parts of the body so constantly in contact, that the perspirable matter, sweat, &c.

cannot easily escape from between them; the skin is inflamed by it, and a partial putrefaction begins to take place, they corrupt and ulcerate. The vessels being thus wounded discharge greater and continual quantities. Hence consumption.

Part of the corrupted matter absorbed again by the vessels and mixed with the blood occasions hectic fevers.

When the body has sweated, not from a dissolution of fluids, but from the force above mentioned, as the sweat dries off, some clammy substance remains in the pores, which closes many of them, wholly or in part. The subsequent perspiration is hereby lessened.

The perspirable matter consists of parts approaching to putrefaction, and therefore destined by nature to be thrown off, that living bodies might not putrefy, which otherwise, from their warmth and moisture, they would be apt to do.

These corrupting particles, if continually thrown off, the remainder of the body continues uncorrupt, or approaches no nearer to a state of putrefaction. Just as in boiling water, no greater degree of heat than the boiling heat can be acquired, because the particles that grow hotter, as fast as they become so, fly off in vapor. But if the vapor could be retained, water might be made much hotter, perhaps red hot, as oil may, which is not so subject to evaporation. So if the perspirable matter is retained it remixes with blood, and pro-

duces first, a slight putrid fever, attending always what we call a cold, and when retained in a great degree, more mischievous putrid diseases.

In hot countries, exercise of body with the heat of the climate create much of this putrid perspirable matter, which ought to be discharged. A check is in those countries very pernicious; putrid malignant violent fevers, and speedy death, the consequence.

Its discharge is also checked another way besides that of closing the pores, viz. by being in an air already full of it, as in close rooms containing great numbers of people, play-houses, ball-rooms, &c.

For air containing a quantity of any kind of vapor, becomes thereby less capable of imbibing more of that vapor, and finally will take no more of it.

If the air will not take it off from the body, it must remain in the body; and the perspiration is as effectually stopped, and the perspirable matter as certainly retained as if the pores were all stopped.

A lock of wet wool contained in a nutmeg grater, may dry, parting with its moisture through the holes of the grater. But if you stop all those holes with wax it will never dry. Nor if exposed to the open air will it dry when the air is as moist as itself. On the contrary if already dry, and exposed to moist air, it would acquire moisture.

Thus people in rooms heated by a multitude of people, find their own bodies heated: thence the quantity of perspirable matter is increased that should be discharged, but the air not being changed grows so full of the same matter, that it will receive no more. So the body must retain it. The consequence is, that next day, perhaps sooner, a slight putrid fever comes on with all the marks of what we call a cold, and the disorder is supposed to be got by coming out of a warm room, whereas it was really taken while in that room.

Putrid ferments beget their like.—Small-pox.—Wet rotten paper, containing corrupt glue. The cold fever communicable by the breath to others, &c.

Urine retained, occasions sneezing, &c.

Coughing and spitting continually, marks of intemperance.

People eat much more than is necessary.

Proportionable nourishment and strength is not drawn from great eating.

The succeeding meals force the preceding through half-undigested.

Small meals continue longer in the body, and are more thoroughly digested.

The vessels being roomy can bear and receive without hurt, an accidental excess.

They can concrete more easily.

There is less quantity of corrupting particles produced.

Putrid fish very bad.
Black hole in the Indies.



LETTER FROM MR. W. SMALL TO DR. FRANKLIN.

DEAR SIR, *Birmingham,* 10*th Aug.* 1771.

THE reason of your having no sooner received the quotation from Celsus, is, that I wished to employ my very first leisure in looking into several other ancient books for passages to the same purpose and to send you all together. But Mr. Keir having told me of your desire to see that immediately, you have it almost alone.

In the article DE TABE in his third book, treating of the cure, he says, "cavendæ *distillationes,* ne, si quid cura levarit, exasperent; et *ob id, vitanda cruditas,* simulque et sol, et frigus."[1] Here indigestion seems to be reckoned the principal cause. If you have not attended to that particular before, you may be surprised to find sunshine among the causes of colds, but such is the doctrine of all the ancients. A passage about the instruments of cure in coughs may perhaps amuse you, "Utilis etiam in omni tussi est pe-

[1] "Great caution should be observed, when relief is once obtained, lest catarrhs are made worse; 'indigestion also, as well as exposure to the sun, and cold air, ought to be avoided."

regrinatio, navigatio longa, loca maritima, *natationes.*"[1]

From several things in Xenophon, and in Plato, the prevailing opinion in their time seems to have been, that what we now commonly call colds and catarrhs, arose almost solely from excess and indolence. On this account Xenophon says, that in Persia in the days of Cyrus, to spit or to blow a nose was infamous. Plato often commends simple spare diet, but in one place he says it prevents all *catarrhs.* Whether he means precisely what we call catarrhs, however, in that passage, may be doubted.

I do not recollect any absolutely express testimony in your favor from Hippocrates. Mucus (of the nose) and saliva he judges to be signs of repletion, and he maintains that persons who drink and eat sparingly are free from diseases occasioned by moisture. Abundance may be found in Galen to your purpose. A modern author, who ought to have understood this subject, for he has written so great a book about catarrhs,[2] that you had better have twenty colds than read it, is of your opinion. "Illa, illa, inquam, cibi potusque abundantia citat catarrhos. Eosdem abigunt frugalitas et labor. Ut ex luxu

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[1] "In all coughs it is found beneficial to take long journeys and voyages, to reside on the sea-coast, and to use sea-baths."

[2] This book upon the Catarrh is probably that of *Schneiderus,* consisting of four volumes 4to.

et otio nascuntur catarrhi, ita horum medicina est in sobrietate, in continentia, in exercitationibus corporis, in mentis tranquillitate. Quotusquisque vero hæc precepta, has leges vivendi custodit? Homo frugi est rara avis, &c. *Hinc* nemo mortalium fere est sine catarrhis."[1]

Mr. Boulton will soon present you with one of the boxes with invisible hinges. He has astonished our rural philosophers exceedingly by calming the waves *à la Franklin*.[2]

I am trying some experiments in relation to the improvement of telescopes; should they answer you shall hear of them.

I beg you will make my most respectful compliments to the fellow travellers who were with you here, and believe me to be with the highest regard, dear Sir, your much obliged and most obedient servant,

W. SMALL.

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[1] "Eating and drinking too much, is sufficient of itself, I say, to produce Catarrhs. Temperance and active pursuits on the contrary drive them away. As Catarrhs are produced by luxury and indolence, so the remedy for these is to observe sobriety, continence, exercise of body and tranquillity of mind. How few observe these precepts? Temperance indeed is very rare. Hence very few escape Catarrhs."

[2] See WRITINGS, Part IV.

ON THE CAUSES OF COLDS.

March 10, 1773.

* * * * * I shall not attempt to explain why damp clothes occasion colds, rather than wet ones, because I doubt the fact; I imagine that neither the one nor the other contribute to this effect, and that the causes of colds are totally independent of wet and even of cold. I propose writing a short paper on this subject, the first moment of leisure I have at my disposal. In the mean time I can only say, that having some suspicions that the common notion, which attributes to cold the property of stopping the pores and obstructing perspiration, was ill founded. I engaged a young physician, who is making some experiments with Sanctorius's balance, to estimate the different proportions of his perspiration, when remaining one hour quite naked, and another warmly clothed. He pursued the experiment in this alternate manner for eight hours successively, and found his perspiration almost double during those hours in which he was naked.

B. FRANKLIN.

May 4, 1773.

The young physician whom I mentioned is dead, and all the notes which he had left of his curious experiments are by some accident lost between our friends Sir John Pringle and Dr. Huck (Saunders);

but these gentlemen, if the papers cannot be recovered, it is to be presumed, will repeat the experiments themselves.[1]

TO DR. RUSH.

DEAR SIR, *London, July* 14, 1773.

I received your favor of May 1, with the pamphlet, for which I am obliged to you. It is well written. I hope that in time the endeavors of the friends to liberty and humanity will get the better of a practice that has so long disgraced our nation and religion.

A few days after I received your packet for M. Dubourg, I had an opportunity of forwarding it to him per M. Poissonier, physician of Paris, who kindly undertook to deliver it. M. Dubourg has been translating my book[2] into French. It is nearly printed, and he tells me he purposes a copy for you.

I shall communicate your judicious remark relating to the septic quality of the air transpired by patients in putrid diseases to my friend Dr. Priestley. I hope that after having discovered the benefit of fresh and cool air applied to the sick,

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[1] The young physician here alluded to, is the late Dr. Stark, whose works, including the above experiments, have since been published.

[2] Experiments in electricity.

people will begin to suspect that possibly it may do no harm to the well. I have not seen Dr. Cullen's book, but am glad to hear that he speaks of catarrhs or colds by contagion. I have long been satisfied from observation, that besides the general colds now termed *influenzas*, (which may possibly spread by contagion as well as by a particular quality of the air) people often catch cold from one another when shut up together in close rooms, coaches, &c. and when sitting near and conversing so as to breathe in each other's transpiration; the disorder being in a certain state. I think too that it is the frowsy corrupt air from animal substances, and the perspired matter from our bodies, which being long confined in beds not lately used, and clothes not lately worn, and books long shut up in close rooms, obtains that kind of putridity which occasions the colds observed upon sleeping in, wearing, and turning over such bed-clothes, or books, and not their coldness or dampness. From these causes, but more from too full living, with too little exercise, proceed in my opinion most of the disorders which for about one hundred and fifty years past the English have called *colds*. As to Dr. Cullen's cold or catarrh *a frigore*, I question whether such a one ever existed. Travelling in our severe winters, I have suffered cold sometimes to an extremity only short of freezing, but this did not make me *catch cold*. And for moisture, I have been in the river every

evening two or three hours for a fortnight together, when one would suppose I might imbibe enough of it to *take cold* if humidity could give it; but no such effect ever followed. Boys never get cold by swimming. Nor are people at sea, or who live at Bermudas, or St. Helena, small islands, where the air must be ever moist from the dashing and breaking of waves against their rocks on all sides, more subject to colds than those who inhabit part of a continent where the air is driest. Dampness may indeed assist in producing putridity and those miasmata which infect us with the disorder we call a cold; but of itself can never by a little addition of moisture hurt a body filled with watery fluids from head to foot. With great esteem and sincere wishes for your welfare, I am, Sir, your most obedient humble servant, B. FRANKLIN.

MOIST AIR NOT UNHEALTHY.

TO DR. PERCIVAL.

London, Oct. 15, 1773.

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—— "THE difference of deaths between 1 in 28 at Manchester, and 1 in 120 at Morton, is surprising. It seems to show the unwholesomeness of the manufacturing life, owing perhaps to the confinement in small close rooms, or in larger with numbers, or to poverty and want of necessaries, or

to drinking, or to all of them. Farmers who manufacture in their own families what they have occasion for and no more, are perhaps the happiest people and the healthiest.

'Tis a curious remark, that moist seasons are the healthiest. The gentry of England are remarkably afraid of moisture, and of air. But seamen, who live in perpetually moist air, are always healthy, if they have good provisions. The inhabitants of Bermuda, St. Helena, and other islands far from continents, surrounded with rocks, against which the waves continually dashing, fill the air with spray and vapor, and where no wind can arrive that does not pass over much sea, and of course bring much moisture, these people are remarkably healthy. And I have long thought that mere moist air has no ill effect on the constitution; though air impregnated with vapors from putrid marshes is found pernicious, not from the moisture but the putridity. It seems strange that a man, whose body is composed in great part of moist fluids, whose blood and juices are so watery, who can swallow quantities of water and small beer daily without inconvenience, should fancy that a little more or less moisture in the air should be of such importance. But we abound in absurdity and inconsistency. Thus though it is generally allowed that *taking the air* is a good thing, yet what caution against air! what stopping of crevices! what wrapping up in warm clothes! what stuffing of

doors and windows! even in the midst of summer. Many London families go out once a day to take the air; three or four persons in a coach, one perhaps sick; these go three or four miles, or as many turns in Hyde Park, with the glasses both up close, all breathing over and over again the same air they brought out of town with them in the coach, with the least change possible, and rendered worse and worse every moment. And this they call *taking the air*. From many years observations on myself and others, I am persuaded we are on a wrong scent in supposing moist or cold air the causes of that disorder we call *a cold*: some unknown quality in the air may perhaps produce colds, as in the *influenza*; but generally I apprehend they are the effect of too full living in proportion to our exercise. Excuse, if you can, my intruding into your province, and believe me ever with sincere esteem, dear sir, your most obedient humble servant,

B. FRANKLIN.

ON LIGHTNING CONDUCTORS.

TO MR. WINTHROP.

London, July 25, 1773.

* * * * YOUR remark on the passage of Castillioneus will be read at the society at their next meeting. I thank you much for the papers and accounts of damage done by lightning, which you have favored

me with. The conductors begin to be used here. Many country seats are provided with them, some churches, the powder magazines at Purfleet, the queen's house in the park, &c. and M. Le Roy, of the Academy of Sciences at Paris, has lately given a Memoir recommending the use of them in that kingdom, which has been long opposed and obstructed by Abbé Nollet. Of the Duke of Tuscany he says, "Ce prince, qui ne connoît pas de délassement plus agréable des soins pénibles du gouvernement, que l'étude de la Physique, a ordonné, l'année dernière, qu'on établît de ces barres au-dessus de tous les magasins à poudre de ses Etats ; on dit que la république de Venise a donné les mêmes ordres," &c. B. FRANKLIN.

OF THE STILLING OF WAVES BY MEANS OF OIL.

EXTRACTED FROM SUNDRY LETTERS BETWEEN DR. FRANKLIN, WILLIAM BROWNRIGG, M.D. F.R.S. AND THE REV. MR. FARISH.

Extract of a Letter from Dr. Brownrigg, to Dr. Franklin, dated Ormathwaite, January 27, 1773.

BY the enclosed from an old friend, a worthy clergyman at Carlisle, whose great learning and extensive knowledge in most sciences would have more distinguished him, had he been placed in a more conspicuous point of view, you will find, that

he had heard of your experiment on Derwent Lake, and has thrown together what he could collect on that subject; to which I have subjoined one experiment from the relation of another gentleman.

Extract of a Letter from the Rev. Mr. Farish to Dr. Brownrigg.

I SOME time ago met with Mr. Dun, who surprised me with an account of an experiment you had tried upon the Derwent water, in company with Sir John Pringle and Dr. Franklin. According to his representation, the water, which had been in a great agitation before, was instantly calmed upon pouring in only a very small quantity of oil, and that to so great a distance round the boat as seemed incredible. I have since had the same accounts from others, but I suspect all of a little exaggeration. Pliny mentions this property of oil as known particularly to the divers, who made use of it in his days, in order to have a more steady light at the bottom.[1] The sailors, I have been

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Note by Dr. Brownrigg.

[1] Sir Gilfred Lawson, who served long in the army at Gibraltar, assures me, that the fishermen in that place are accustomed to pour a little oil on the sea, in order to still its motion, that they may be enabled to see the oysters lying at its bottom, which

told, have observed something of the same kind in our days, that the water is always remarkably smoother, in the wake of a ship that has been newly tallowed, than it is in one that is foul. Mr. Pennant also mentions an observation of the like nature made by the seal-catchers in Scotland. *Brit. Zool.* Vol. IV. *Article* Seal. When these animals are devouring a very oily fish, which they always do under water, the waves above are observed to be remarkably smooth, and by this mark the fishermen know where to look for them. Old Pliny does not usually meet with all the credit I am inclined to think he deserves. I shall be glad to have an authentic account of the Keswick experiment; and if it comes up to the representations that have been made of it, I shall not much hesitate to believe the old gentleman in another more wonderful phenomenon he relates of stilling a tempest only by throwing up a little vinegar into the air.

Dr. Franklin to Dr. Brownrigg.

Dear Sir, *London, Nov.* 7, 1773.

I thank you for the remarks of your learned friend at Carlisle: I had, when a youth, read and

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are there very large, and which they take up with a proper instrument. This Sir Gilfred had often seen performed, and said the same was practised on other parts of the Spanish coast.

smiled at Pliny's account of a practice among the seamen of his time, to still the waves in a storm by pouring oil into the sea; which he mentions, as well as the use of oil by the divers; but the stilling a tempest by throwing vinegar into the air had escaped me. I think with your friend, that it has been of late too much the mode to slight the learning of the ancients. The learned, too, are apt to slight too much the knowledge of the vulgar. The cooling by evaporation was long an instance of the latter. This art of smoothing the waves by oil is an instance of both.

Perhaps you may not dislike to have an account of all I have heard, and learnt, and done in this way. Take it, if you please, as follows:

In 1757, being at sea in a fleet of 96 sail, bound against Louisbourg, I observed the wakes of two of the ships to be remarkably smooth, while all the others were ruffled by the wind, which blew fresh. Being puzzled with the differing appearance, I at last pointed it out to our captain, and asked him the meaning of it. "The cooks," says he, "have, I suppose, been just emptying their greasy water through the scuppers, which has greased the sides of those ships a little;" and this answer he gave me with an air of some little contempt, as to a person ignorant of what every body else knew. In my own mind I at first slighted his solution, though I was not able to think of another; but recollecting what I had formerly read in Pliny, I resolved to

make some experiment of the effect of oil on water, when I should have an opportunity.

Afterwards being again at sea in 1762, I first observed the wonderful quietness of oil on agitated water, in the swinging glass lamp I made to hang up in the cabin, as described in my printed paper.[1] This I was continually looking at and considering, as an appearance to me inexplicable. An old sea captain, then a passenger with me, thought little of it, supposing it an effect of the same kind with that of oil put on water to smooth it, which he said was a practice of the Bermudians, when they would strike fish, which they could not see if the surface of the water was ruffled by the wind. This practice I had never before heard of, and was obliged to him for the information; though I thought him mistaken as to the sameness of the experiment, the operations being different as well as the effects. In one case, the water is smooth till the oil is put on, and then becomes agitated. In the other it is agitated before the oil is applied, and then becomes smooth. The same gentleman told me, he had heard it was a practice with the fishermen of Lisbon, when about to return into the river, (if they saw before them too great a surf upon the bar, which they apprehended might fill their boats in passing,) to empty a bottle or two of oil into the sea, which would suppress the breakers, and allow

[1] See the preceding paper.

them to pass safely. A confirmation of this I have not since had an opportunity of obtaining; but discoursing of it with another person, who had often been in the Mediterranean, I was informed, that the divers there, who, when under water in their business, need light, which the curling of the surface interrupts by the refractions of so many little waves, let a small quantity of oil now and then out of their mouths, which rising to the surface smooths it, and permits the light to come down to them. All these informations I at times revolved in my mind, and wondered to find no mention of them in our books of experimental philosophy.

At length being at Clapham, where there is, on the common, a large pond, which I observed one day to be very rough with the wind, I fetched out a cruet of oil, and dropped a little of it on the water. I saw it spread itself with surprising swiftness upon the surface; but the effect of smoothing the waves was not produced: for I had applied it first on the leeward side of the pond, where the waves were largest, and the wind drove my oil back upon the shore. I then went to the windward side, where they began to form; and there the oil, though not more than a tea-spoonful, produced an instant calm over a space several yards square, which spread amazingly, and extended itself gradually till it reached the lee side, making

all that quarter of the pond, perhaps half an acre, as smooth as a looking-glass.

After this I contrived to take with me, whenever I went into the country, a little oil in the upper hollow joint of my bamboo cane, with which I might repeat the experiment as opportunity should offer; and I found it constantly to succeed.

In these experiments, one circumstance struck me with particular surprise. This was the sudden, wide, and forcibly spreading of a drop of oil on the face of the water, which I do not know that any body has hitherto considered. If a drop of oil is put on a highly polished marble table, or on a looking-glass that lies horizontally, the drop remains in its place, spreading very little. But when put on water, it spreads instantly many feet round, becoming so thin as to produce the prismatic colors, for a considerable space, and beyond them so much thinner as to be invisible, except in its effect of smoothing the waves at a much greater distance. It seems as if a mutual repulsion between its particles took place as soon as it touched the water, and a repulsion so strong as to act on other bodies swimming on the surface, as straw, leaves, chips, &c. forcing them to recede every way from the drop, as from a centre, leaving a large clear space. The quantity of this force, and the distance to which it will operate, I have not

yet ascertained; but I think it a curious inquiry, and I wish to understand whence it arises.

In our journey to the north, when we had the pleasure of seeing you at Ormathwaite, we visited the celebrated Mr. Smeaton, near Leeds. Being about to show him the smoothing experiment on a little pond near his house, an ingenious pupil of his, Mr. Jessop, then present, told us of an odd appearance on that pond, which had lately occurred to him. He was about to clean a little cup in which he kept oil, and he threw upon the water some flies that had been drowned in the oil. These flies presently began to move, and turned round on the water very rapidly, as if they were vigorously alive, though on examination he found they were not so. I immediately concluded that the motion was occasioned by the power of the repulsion above mentioned, and that the oil issuing gradually from the spungy body of the fly continued the motion. He found some more flies drowned in oil, with which the experiment was repeated before us. To show that it was not any effect of life recovered by the flies, I imitated it by little bits of oiled chips and paper cut in the form of a comma, of the size of a common fly; when the stream of repelling particles issuing from the point made the comma turn round the contrary way. This is not a chamber experiment; for it cannot be well repeated in a bowl or dish of

water on a table. A considerable surface of water is necessary to give room for the expansion of a small quantity of oil. In a dish of water, if the smallest drop of oil be let fall in the middle, the whole surface is presently covered with a thin greasy film proceeding from the drop; but as soon as that film has reached the sides of the dish, no more will issue from the drop, but it remains in the form of oil, the sides of the dish putting a stop to its dissipation by prohibiting the farther expansion of the film.

Our friend, Sir John Pringle, being soon after in Scotland, learned there, that those employed in the herring fishery could at a distance see where the shoals of herrings were, by the smoothness of the water over them, which might possibly be occasioned, he thought, by some oiliness proceeding from their bodies.

A gentleman from Rhode Island told me, it had been remarked, that the harbor of Newport was ever smooth while any whaling vessels were in it: which probably arose from hence, that the blubber which they sometimes bring loose in the hold, or the leakage of their barrels, might afford some oil to mix with that water, which from time to time they pump out to keep their vessel free, and that some oil might spread over the surface of the water in the harbor, and prevent the forming of any waves.

This prevention I would thus endeavor to explain.

There seems to be no natural repulsion between water and air, such as to keep them from coming into contact with each other. Hence we find a quantity of air in water; and if we extract it by means of the air-pump, the same water, again exposed to the air, will soon imbibe an equal quantity.

Therefore air in motion, which is wind, in passing over the smooth surface of water, may rub, as it were, upon that surface, and raise it into wrinkles, which if the wind continues, are the elements of future waves.

The smallest wave once raised does not immediately subside, and leave the neighboring water quiet; but in subsiding raises nearly as much of the water next to it, the friction of the parts making little difference. Thus a stone dropped in a pool raises first a single wave round itself; and leaves it, by sinking to the bottom; but that first wave subsiding raises a second, the second a third, and so on in circles to a great extent.

A small power continually operating will produce a great action. A finger applied to a weighty suspended bell can at first move it but little; if repeatedly applied, though with no greater strength, the motion increases till the bell swings to its utmost height, and with a force that cannot be

resisted by the whole strength of the arm and body. Thus the small first-raised waves, being continually acted upon by the wind, are, though the wind does not increase in strength, continually increased in magnitude, rising highly and extending their bases, so as to include a vast mass of water in each wave, which in its motion acts with great violence.

But if there be a mutual repulsion between the particles of oil, and no attraction between oil and water, oil dropped on water will not be held together by adhesion to the spot whereon it falls; it will not be imbibed by the water; it will be at liberty to expand itself; and it will spread on a surface that, besides being smooth to the most perfect degree of polish, prevents, perhaps by repelling the oil, all immediate contact, keeping it at a minute distance from itself: and the expansion will continue till the mutual repulsion between the particles of the oil is weakened and reduced to nothing by their distance.

Now I imagine that the wind, blowing over water thus covered with a film of oil, cannot easily *catch* upon it, so as to raise the first wrinkles, but slides over it, and leaves it smooth as it finds it. It moves a little the oil indeed, which being between it and the water, serves it to slide with, and prevents friction, as oil does between those parts of a machine, that would otherwise rub hard together. Hence the oil dropped on the wind-

ward side of a pond proceeds gradually to leeward, as may be seen by the smoothness it carries with it, quite to the opposite side. For the wind being thus prevented from raising the first wrinkles, that I call the elements of waves, cannot produce waves, which are to be made by continually acting upon, and enlarging those elements, and thus the whole pond is calmed.

Totally therefore we might suppress the waves in any required place, if we could come at the windward place where they take their rise. This in the ocean can seldom if ever be done. But perhaps something may be done on particular occasions, to moderate the violence of the waves when we are in the midst of them, and prevent their breaking where that would be inconvenient.

For when the wind blows fresh, there are continually rising on the back of every great wave a number of small ones, which roughen its surface, and give the wind hold, as it were, to push it with greater force. This hold is diminished, by preventing the generation of those small ones. And possibly too, when a wave's surface is oiled, the wind, in passing over it, may rather in some degree press it down, and contribute to prevent it rising again, instead of promoting it.

This as mere conjecture would have little weight, if the apparent effects of pouring oil into the midst of waves were not considerable, and as yet not otherwise accounted for.

When the wind blows so fresh, as that the waves are not sufficiently quick in obeying its impulse, their tops being thinner and lighter are pushed forward, broken, and turned over in a white foam. Common waves lift a vessel without entering it; but these when large sometimes break above and pour over it, doing great damage.

That this effect might in any degree be prevented, or the height and violence of waves in the sea moderated, we had no certain account; Pliny's authority for the practice of seamen in his time being slighted. But discoursing lately on this subject with his excellency Count Bentinck, of Holland, his son, the honorable Captain Bentinck, and the learned professor Allemand, (to all whom I showed the experiment of smoothing in a windy day the large piece of water at the head of the Green Park,) a letter was mentioned, which had been received by the count from Batavia, relative to the saving of a Dutch ship in a storm by pouring oil into the sea. I much desired to see that letter; and a copy of it was promised me, which I afterward received, and is as follows:

Extract of a letter from Mr. Tengnagel to Count Bentinck, dated at Batavia, the 5th of January, 1770.

"Near the islands Paul and Amsterdam, we met with a storm, which had nothing particular in it worthy of being communicated to you, except

that the captain found himself obliged, for greater safety in wearing the ship, to pour oil into the sea, to prevent the waves breaking over her, which had an excellent effect, and succeeded in preserving us. As he poured out but a little at a time, the East India Company owes perhaps its ship to only six demi-ames of olive-oil. I was present upon deck when this was done; and I should not have mentioned this circumstance to you, but that we have found people so prejudiced against the experiment, as to make it necessary for the officers on board and myself to give a certificate of the truth on this head, of which we made no difficulty."

On this occasion, I mentioned to captain Bentinck, a thought which had occurred to me in reading the voyages of our late circumnavigators, particularly where accounts are given of pleasant and fertile islands which they much desired to land upon, when sickness made it more necessary, but could not effect a landing through a violent surf breaking on the shore, which rendered it impracticable. My idea was, that possibly by sailing to and fro at some distance from such lee-shore, continually pouring oil into the sea, the waves might be so much depressed and lessened before they reach the shore, as to abate the height and violence of the surf, and permit a landing; which, in such circumstances, was a point of sufficient importance to justify the expense of the oil that

might be requisite for the purpose. That gentleman, who is ever ready to promote what may be of public utility, though his own ingenious inventions have not always met with the countenance they merited, was so obliging as to invite me to Portsmouth, where an opportunity would probably offer, in the course of a few days, of making the experiment on some of the shores about Spithead, in which he kindly proposed to accompany me, and to give assistance with such boats as might be necessary. Accordingly, about the middle of October last, I went with some friends to Portsmouth: and a day of wind happening, which made a lee-shore between Hasler Hospital and the point near Jillkecker, we went from the Centaur with the long-boat and barge towards that shore. Our disposition was this: the long-boat was anchored about a quarter of a mile from the shore; part of the company were landed behind the point, (a place more sheltered from the sea.) who came round and placed themselves opposite to the long-boat, where they might observe the surf, and note if any change occurred in it upon using the oil. Another party, in the barge, plied to windward of the long-boat, as far from her as she was from the shore, making trips of about half a mile each, pouring oil continually out of a large stone bottle, through a hole in the cork, somewhat bigger than a goose-quill. The experiment had not, in the main point, the success we wished, for

no material difference was observed in the height or force of the surf upon the shore; but those who were in the long-boat could observe a tract of smoothed water, the whole of the distance in which the barge poured the oil, and gradually spreading in breadth towards the long-boat. I call it smoothed, not that it was laid level; but because, though the swell continued, its surface was not roughened by the wrinkles, or smaller waves, before mentioned; and none or very few white caps (or waves whose tops turn over in foam,) appeared in that whole space, though to windward and leeward of it there were plenty; and a wherry, that came round the point under sail, in her way to Portsmouth, seemed to turn into that tract in preference, and to use it from end to end, as a piece of turnpike-road.

It may be of use to relate the circumstances of an experiment that does not succeed, since they may give hints of an amendment in future trials: it is therefore I have been thus particular. I shall only add what I apprehend may have been the reason of our disappointment.

I conceive, that the operation of oil on water is, first, to prevent the raising of new waves by the wind; and, secondly, to prevent its pushing those before raised with such force, and consequently their continuance of the same repeated height, as they would have done, if their surface were not oiled. But oil will not prevent waves being raised

by another power, by a stone, for instance, falling into a still pool; for they then rise by the mechanical impulse of the stone, which the greasiness on the surrounding water cannot lessen or prevent, as it can prevent the winds catching the surface and raising it into waves. Now waves once raised, whether by the wind or any other power, have the same mechanical operation, by which they continue to rise and fall, as a *pendulum* will continue to swing, a long time after the force ceases to act by which the motion was first produced: that motion will, however, cease in time; but time is necessary. Therefore, though oil spread on an agitated sea may weaken the push of the wind on those waves whose surfaces are covered by it, and so, by receiving fresh impulse, they may gradually subside; yet a considerable time, or a distance through which they will take time to move, may be necessary to make the effect sensible on any shore in a diminution of the surf: for we know, that when wind ceases suddenly, the waves it has raised do not as suddenly subside, but settle gradually, and are not quite down till after the wind has ceased. So though we should, by oiling them, take off the effect of wind on waves already raised, it is not to be expected that those waves should be instantly levelled. The motion they have received, will for some time continue; and if the shore is not far distant, they arrive there so soon, that their effect upon it will not be visibly

diminished. Possibly, therefore, if we had begun our operations at a greater distance, the effect might have been more sensible. And perhaps we did not pour oil in sufficient quantity. Future experiments may determine this.

I was, however, greatly obliged to Captain Bentinck, for the cheerful and ready aids he gave me: and I ought not to omit mentioning Mr. Banks, Dr. Solander, General Cardac, and Dr. Blagden, who all assisted at the experiment, during that blustering unpleasant day, with a patience and activity that could only be inspired by a zeal for the improvement of knowledge, such especially as might possibly be of use to men in situations of distress.

I would wish you to communicate this to your ingenious friend, Mr. Farish, with my respects: and believe me to be, with sincere esteem, dear sir, your most obedient humble servant, B. FRANKLIN.

AN ATTEMPT TO EXPLAIN THE EFFECTS OF LIGHTNING ON THE VANE OF THE STEEPLE OF A CHURCH IN CREMONA, AUGUST, 1777.

TO DR. JOHN INGENHAUSZ.

1. When the subtile fluid which we call fire or heat enters a solid body, it separates the particles of which that body consists farther from each other, and thus dilates the body, increasing its dimensions.

2. A greater proportion of fire introduced separates the parts so far from each other that the solid body becomes a fluid, being melted.

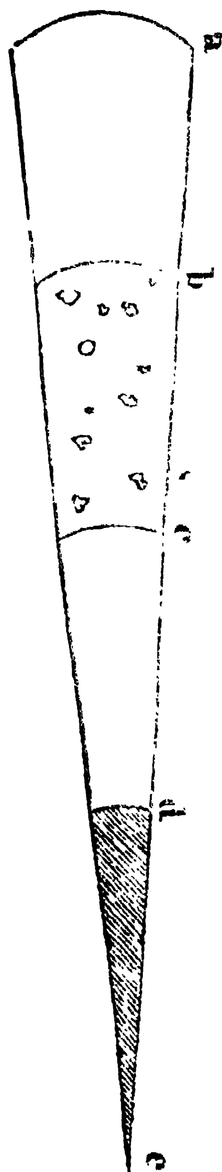
3. A still greater quantity of heat separates the parts so far, that they lose their mutual attraction, and acquire a mutual repulsion, whence they fly from each other, either gradually or suddenly, with great force, as the separating power is introduced gradually or suddenly.

4. Thus ice becomes water, and water vapor, which vapor is said to expand to 14,000 times the space it occupied in the form of water, and with an explosive force in certain cases capable of producing great and violent effects.

5. Thus metals expand, melt, and explode. The two first effected by the gradual application of the separating power, and all three, in its sudden application by artificial electricity, or lightning.

6. That fluid in passing through a metal rod or wire is generally supposed to occupy the whole dimension of the rod. If the rod is smaller in some places than in others, the quantity of fluid which is not sufficient to make any change in the larger or thicker part, may be sufficient to expand, melt or explode the smaller, the quantity of fluid passing, being the same, and the quantity of matter less that is acted upon.

7. Thus the links of a brass chain, with a certain quantity of electricity passing through them have been melted in the small parts that form their contact while the rest have not been affected.



8. Thus a piece of tin foil cut in this form, enclosed in a pack of cards, and having the charge of a large bottle sent through it, has been found unchanged in the broadest part between a and b, melted only in spots between c and d, and the part between d and e reduced to smoke by explosion.

9. The tin foil melted in spots between b and c, and that whole space not being melted, seems to indicate that the foil in the melted parts had been thinner than the rest, on which thin parts the passing fluid had therefore a greater effect.

10. Some metals melt more easily than others. Tin more easily than copper, copper than iron. It is supposed (perhaps not yet proved) that those which melt with the least of the separating power, whether that be common fire or the electric fluid, do also explode with less of that power.

11. The explosions of metal, like those of gunpowder, act in all directions. Thus the explosion of gold leaf between plates of glass breaking the glass to pieces, will throw those pieces into all parts of the room, and the explosion of iron or even of water between the joints of stone in a steeple, will scatter the stones in all directions round

the neighborhood. But the directions given to those stones by the explosion, is to be considered as different from the direction of the lightning which happened to occasion those explosions of the matter it met with in its passage between the clouds and the earth.

12. When bodies positively electrised approach sharp pointed rods or thin plates of metal, these are more easily rendered negative by the repulsive force of the electric fluid in those positively electrised bodies, which chases away the natural quantity contained in those mince rods or plates, though it would not have force enough to chase the same out of larger masses. Hence such points, rods and plates being in a negative state, draw to themselves more strongly and in greater quantities the electric fluid offered them, than such masses can do which remain nearly in their natural state. And thus a pointed rod receives not only at its point, though more visibly there, but at all parts of its length that are exposed. Hence a needle held between the finger and thumb, and presented to a charged prime conductor, will draw off the charge more expeditiously if held near the eye, and the rest of its length is exposed to the electrical atmosphere, than if all but half an inch of the point is concealed and covered.

13. Lightning so differs from solid projectiles, and from common fluids projected with violence, that though its course is rapid, it is most easily

turned to follow the direction of good conductors. And it is doubted whether any experiments in electricity have yet decisively proved, that the electric fluid in its violent passage through the air where a battery is discharged has what we call a momentum, which would make it continue its course in a right line, though a conductor offered near that course to give it a different, or even contrary direction; or that it has a force capable of pushing forward, or overthrowing the objects it strikes against, even though it sometimes pierces them. Does not this seem to indicate that the perforation is not made by the force of a projectile passing through, but rather by the explosion or the dilatation in passing, of a subtile line of fluid?

14. Such an explosion or dilatation of a line of fluid passing through a card, would raise burrs round the hole sometimes on one side, sometimes on the other, and sometimes on both, according to the disposition of the part of the paper near the surface, without any regard to the direction of the fluid.

15. Great thanks are due to the ingenious philosopher who examined the vane at Cremona, and who took the pains to describe so exactly the effects of the lightning upon it, and to communicate that description. The fact is extremely curious. It is well worth considering. He invites to that consideration. He has fairly given his own opinion. He will with candor receive that of

others, though it may happen to differ from his own. By calmly discussing rather than by warmly disputing, the truth is most easily obtained. I shall give my opinion freely, as it is asked, hoping it may prove the true one; and promising myself if otherwise, the honor at least of acknowledging frankly my error, and of being thankful to him who kindly shews it to me.

16. By the account given of this stroke of lightning upon the steeple of Cremona, it appears that the rod of iron or spindle on which the vane turned was of about two inches circumference, terminating in a cross above the vane, and its lower end fixed in a marble pedestal.

17. That the plate of the vane was copper, eight or nine inches wide, and near twice as long. That it was about one line thick near the spindle, and growing thinner insensibly towards the other end, where its thickness did not exceed three quarters of a line, the weight $20\frac{1}{2}$ ounces.

18. That the copper had been tinned over.

19 That the marble pedestal was split by the stroke into many pieces, and scattered over the roof, garden, and court of a neighboring building. One piece was thrown to the distance of 40 feet. The spindle was broken and displaced, and the vane thrown on the roof of the parsonage house 20 feet from the steeple.

20. That the vane was perforated in 18 places, the holes of irregular forms, and the metal which

had filled them pushed outwards in some of them on one side of the vane, in others on the other. The copper shewed marks of having been partly melted, and in some places tin and copper melted and mixed together. There were marks of smoke in several places.

21. The ragged parts bent outwards round each hole, being brought back to their original flat position, were not, though evidently a little thinned and dilated, sufficient to fill the place.

22. From the effects described (19,) it is clear that the quantity of lightning which fell on this steeple at Cremona was very great.

23. The vane being a thin plate of copper, its edges and corners may be considered as a series of points, and being therefore sooner rendered negative by the repulsive force of an approaching positive cloud than the blunt and thick iron cross, (12,) was probably first struck; and thence became the conductor of that great quantity.

24. The plate of which the vane was formed being thicker near the spindle, and diminishing in thickness gradually to the other end, (17,) was probably not of copper plated by passing between rollers, for they would have left it of equal thickness; but of metal plated by the hammer. The surface too of rolled copper is even and plain, that of hammered is generally uneven, with hollows occasioned by the impressions of the hammer.

25. In those concave impressions the metal is

thinner than it is around them, and probably thinnest near the centre of each impression.

26. The lightning which in passing through the vane was not sufficient to melt its thicker parts, might be sufficient to melt the thinner, (6, 7, 8, 9,) and to soften those that were in a middle state.

27. The part of the tin (18,) which covered the thinner parts being more easily melted and exploded than copper, (10,) might possibly be exploded when the copper was but melted. The smoke appearing in several places, (20,) is a proof of explosion.

28. There might probably be more tin in the concave impressions of the hammer on one side of the plate, than on the convex part of those impressions on the other. Hence stronger explosions on the concave side.

29. The nature of those explosions is to act violently in all directions; and in this case being near the plate they would act against it on one side, while they acted against the air on the other.

30. These thin parts of the plate being at the same instant partly in fusion, and partly so softened as to be near it; the softened parts were pushed outwards, a hole made, and some of the melted parts blown away; hence there was not left metal enough to refill the vacancy by bending back the ragged parts to their places.

31. The concave impressions of the hammer being indifferently made on both sides of the plate,

it is natural from 28, 29, 30, that the pushing outwards of the softened metal by explosions, should be on both sides of the plate nearly equal.

32. That the force of a simple electrical explosion is very great, appears from the Geneva experiment, wherein a spark between two wires, under oil in a drinking glass, breaks the glass, body, stem, and foot, all to shivers.

33. The electric explosion of metal acts with still more force. A strip of leaf gold no broader than a straw, exploded between two pieces of thick looking-glass, will break the glass to pieces, though confined by the screws of a strong press. And between two pieces of marble pressed together by a weight of 20 pounds, will lift that weight. Much less force is necessary to move the melted and softened parts of a thin plate of copper.

34. This explication of the appearances on the vane, is drawn from what we already know of electricity and the effects of lightning. The learned author of the account gives a different but very ingenious one, which he draws from the appearances themselves. The matter pushed out of the holes is found, that of some on one side of the plate, and of others on the other. Hence he supposes them to be occasioned (if I understand him right) by streams or threads of electric matter of different and contrary kinds, rushing violently towards each other, and meeting with the vane, so accidentally placed, as to be found precisely in the

place of their meeting, where it was pierced by all of them, they all striking on both its sides at the same instant. This however is so extraordinary an accident, as to be in the authors own opinion almost miraculous, "Passeranno (says he) forse piu secoti prima que ritorni tralle infinite combinazioni un caso similé a quello della banderuola che ora abbiamo per mano. Forza é que si essaurisca una non piu udita miniera difulmini sopra una grande citta, pressoque seminata di campanili e di banderuole, il che e raris simo; e può ancora volti cio succedere, senza che s'incontri giammai un altera, banderuola tanto opportunetamente situata tra i limiti della fulminea explosione."

35. But though the author's explication of these appearances of the vane does not satisfy me, I am not so confident of my own as to propose its being accepted without confirmation by experiment. Those who have strong electric batteries may try it thus: form a little vane of paper, and spot it on both sides by attaching small pieces of leaf gold or tin foil, not exactly opposite to each other: then send the whole force of the battery through the vane, entering at one end of it and going out at the other. If the metal explodes, I imagine it will be found to make holes in the paper, forcing the torn parts out on the sides opposite to the metal. A more expensive but perhaps a more satisfactory experiment would be, to make a new vane as exactly as possible like that in question, in all the

particulars of its description, and place it on a tall mast fixed on some hill subject to strokes of lightning, with a better conductor to the earth than the wood of the mast; if this should be struck in the course of a few years, and the same effects appear upon it, it would be still more miraculous to suppose it happened by accident to be exactly situated where those crossing threads of different electricities were afterwards to meet.

36. The perforation of glass bottles when overcharged is, I imagine, a different case, and not explicable by either of these hypothesis. I cannot well suppose the breach to be occasioned by the passage of electricity through it, since a single bottle, though so broken in the discharge, always is found to send round in its usual course the quantity with which it was charged. Then the breach never happens but at the instant of the circuitous discharge, either by the discharging rod, or in overleaping the borders of the glass. Thus I have been present when a battery of twenty glasses was discharged by the discharging rod, and produced the same effect in its circuit as if none of the bottles had been pierced; and yet on examining them, we found no less than twelve of them in that situation. Now all the bottles of the battery being united by a communication of all the outsides together, and of all the insides together, if one of them had been pierced by a forced passage of the different kinds of electricity to meet each other, before the dis-

charge by the discharging rod, it would not only have prevented the passage of the electricity by the common circuit, but it would have saved all the rest of its fellows, by conducting the whole through its own breach. And it is not easy to conceive that 12 bottles in 20 should be so equally strong as to support the whole strength of their charge, till the circuit of their discharge was opened, and then be so equally weak as to break altogether when the weight of that charge was taken off from them by opening the circuits. At some other time I will give you my opinion of this effect if you desire it.

I have taken the account of this stroke of lightning from an Italian piece, intitled *Analisi d'un nuovo fenomeno del fulmine*, the dedication of which is subscribed *Carlo Barletti delle Sacolo Pic*, who I suppose is the author. As I do not perfectly understand that language, I may possibly in some things have mistaken that philosopher's meaning. I therefore desire, my dear friend, that you would not permit this to be published, till you have compared and considered it with that original piece, and communicated to me your remarks and corrections. Nor would I in any case have it appear with my name, as perhaps it may occasion disputes, and I have no time to attend to them.

ON ELECTRICITY.

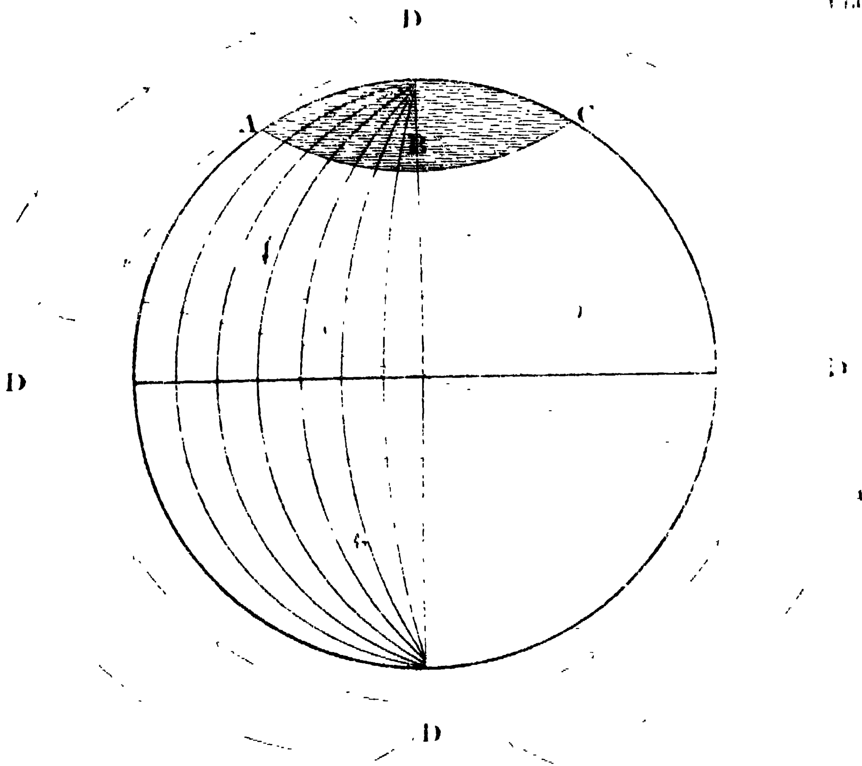
THE LEYDEN BOTTLE, AND M. VOLTA'S EXPERIMENT.

To * * * * * *.

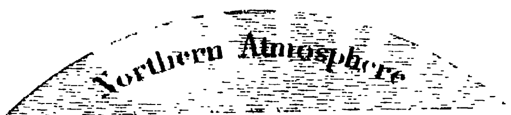
Paris, 1778.

I THANK you for the account you give me of M. Volta's experiment. You judge rightly in supposing that I have not much time at present to consider philosophical matters; but as far as I understand it from your description, it is only another form of the Leyden Phial, and explicable by the same principles. I must however own myself puzzled by one part of your account, viz. "and thus the electric force once excited may be kept alive years together," which is perhaps only a mistake. I have known it indeed to be continued many months in a phial hermetically sealed, and suppose it may be so preserved for ages; but though one may, by repeatedly touching the knob of a charged bottle with a small insulated plate, like the upper one of the electrophore, draw an incredible number of sparks successively, that is, one after every touch, and those for a while not apparently different in magnitude, yet at length they will become small, and the charge be finally exhausted. But I am in the wrong to give my opinion till I have seen the experiment.

I like much your pasteboard machine, and think it may, in some respects, be preferable to the very



The Arrows represent the general Currents of the Air.
A.B.C *the great Cake of Ice & Snow in the Polar Regions.*
D.D.D.D. *the Medium Height of the Atmosphere.*
The Representation is made only for one Quarter and one Meridian of the Globe; but is to be understood the same for all the rest.



large glass ones constructed here. The Duke de Chaulnes has one, said, if I remember right, to be five feet in diameter. I saw it tried, but it happened not to be in order. B. F.

AURORA BOREALIS.

Suppositions and Conjectures towards forming an Hypothesis for its Explanation, 1779.

1. Air heated by any means becomes rarefied and specifically *lighter* than other air in the same situation not heated.

2. Air being thus made lighter rises, and the neighboring cooler heavier air takes its place.

3. If in the middle of a room you heat the air by a stove, or pot of burning coals near the floor, the heated air will *rise* to the ceiling, spread there over the cooler air till it comes to the cold walls; there being condensed and made heavier, it *descends* to supply the place of that cool air which had moved towards the stove or fire, in order to supply the place of the heated air which had ascended from the space around the stove or fire.

4. Thus there will be a continual circulation of air in the room, which may be rendered visible by making a little smoke; for that smoke will rise and circulate with the air.

5. A similar operation is performed by nature on the air of the globe. Our atmosphere is of a certain height, perhaps at a medium [ ] miles.

Above that height it is so rare as to be almost a vacuum. The air heated between the tropics is continually rising, and its place is supplied by northerly and southerly winds which come from those cool regions.

6. The light heated air floating above the cooler and denser, must spread northward and southward, and descend near the two poles, to supply the place of the cooler air which had moved towards the equator.

7. Thus a circulation of air is kept up in our atmosphere as in the room above mentioned.

8. That heavier and lighter air may move in currents of different and even opposite directions, appears sometimes by the clouds that happen to be in these currents, as plainly as by the smoke in the experiment above mentioned. Also in opening a *door* between two chambers, one of which has been warmed, by holding a candle near the top, near the bottom, and near the middle, you will find a strong current of warm air passing out of the warmed room *above*, and another of cool air entering it *below*, while in the middle there is little or no motion.

9. The great quantity of vapor rising between the tropics forms clouds, which contain much electricity.

Some of them fall in rain, before they come to the polar regions.

10. If the rain be received in an isolated vessel,

the vessel will be electrified; for every drop brings down some electricity with it.

11. The same is done by snow and hail.

12. The electricity so descending in temperate climates, is received and imbibed by the earth.

13. If the clouds are not sufficiently discharged by this means, they sometimes discharge themselves suddenly by striking into the earth, where the earth is fit to receive their electricity.

14. The earth in temperate and warm climates is generally fit to receive it, being a good conductor.

15. A certain quantity of heat will make some bodies good conductors that will not otherwise conduct.

16. Thus wax rendered fluid, and glass softened by heat, will both of them conduct.

17. And water, though naturally a good conductor, will not conduct well when frozen into ice by a common degree of cold; not at all where the cold is extreme.

18. Snow falling upon frozen ground has been found to retain its electricity; and to communicate it to an isolated body, when after falling, it has been driven about by the wind.

19. The humidity contained in all the equatorial clouds that reach the polar regions, must there be condensed and fall in snow.

20. The great cake of ice that eternally covers those regions may be too hard frozen to permit the

electricity, descending with that snow, to enter the earth.

21. It will therefore be *accumulated upon that ice.*

22. The atmosphere being heavier in the polar regions, than in the equatorial, will there be lower; as well from that cause, as from the smaller effect of the centrifugal force: consequently the distance to the vacuum above the atmosphere will be less at the poles than elsewhere; and probably much less than the distance (upon the surface of the globe) extending from the pole to those latitudes in which the earth is so thawed as to receive and imbibe electricity; the frost continuing to lat. 80., which is 10 degrees or 600 miles from the pole, while the height of the atmosphere there of such density as to obstruct the motion of the electric fluid, can scarce be estimated above [ ] miles.

23. The *vacuum* above is a good conductor.

24. May not then the great quantity of electricity brought into the polar regions by the clouds, which are condensed there, and fall in snow, which electricity would enter the earth, but cannot penetrate the ice; may it not, I say *(as a bottle overcharged)* break through that low atmosphere and run along in the vacuum over the air towards the equator, diverging as the degrees of longitude enlarge, strongly visible where densest, and becoming less visible as it more diverges; till it finds a passage to the earth in more temperate climates, or is mingled with their upper air?

25. If such an operation of nature were really performed, would it not give all the appearances of an AURORA BOREALIS?

26. And would not the auroræ become more frequent *after the approach of winter;* not only because more visible in longer nights; but also because in summer the long presence of the sun may soften the surface of the great ice cake, and render it a conductor, by which the accumulation of electricity in the polar regions will be prevented?

27. The *atmosphere of the polar regions* being made more dense by the extreme cold, and all the moisture in that air being frozen, may not any great light arising therein, and passing through it, render its density in some degree visible during the night-time, to those who live in the rarer air of more southern latitudes? and would it not in that case, although in itself a complete and full circle, extending perhaps ten degrees from the pole, appear to spectators so placed, (who could see only a part of it) *in the form of a segment,* its chord resting on the horizon, and its arch elevated more or less above it as seen from latitudes more or less distant, *darkish in color,* but yet sufficiently *transparent* to permit some stars to be seen through it?

28. The rays of electric matter issuing out of a body, diverge by mutually repelling each other, unless there be some conducting body near to receive them: and if that conducting body be at a

greater distance, they will *first diverge*, and then *converge* in order to enter it. May not this account for some of the varieties of figure seen at times in the *motions* of the luminous matter of the auroræ; since it is possible, that in passing over the atmosphere, from the north, in all directions or meridians, towards the equator, the rays of that matter may find, in many places portions of cloudy region, or moist atmosphere under them, which (being in the natural or negative state) may be fit to receive them, and towards which they may therefore converge; and when one of those receiving bodies is more than saturated, they may *again* diverge from it, towards other surrounding masses of such humid atmosphere, and thus form the *crowns*, as they are called, and other figures mentioned in the histories of this meteor?

29. If it be true that the clouds which go to the polar regions carry thither the vapors of the equatorial and temperate regions, which vapors are condensed by the extreme cold of the polar regions, and fall in snow or hail; the winds which come from those regions ought to be generally dry, unless they gain some humidity by sweeping the ocean in their way; and if I mistake not, the winds between the north-west and north-east are, for the most part dry, when they have continued some time.[1]

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[1] In one of the copies of this paper there is a line drawn across this last article

[In the Philosophical Transactions for 1774, p. 122, is a letter from Mr. J. S. Winn, to Dr. Franklin, stating, that since he had first made the observation concerning the south or south-west winds succeeding an aurora, he had found it invariably obtaining in twenty-three instances; and he adds in a note a fresh confirming instance. In reply, Dr. Franklin makes the following conjecture.]

The *auroræ boreales*, though visible almost every night of clear weather in the more northern regions, and very high in the atmosphere, can scarce be visible in England but when the atmosphere is pretty clear of clouds for the whole space between us and those regions; and therefore are seldom visible there. This extensive clearness may have been produced by a long continuance of northerly winds. When the winds have long continued in one quarter the return is often violent. Allowing the fact so repeatedly observed by Mr. Winn, perhaps this may account for the violence of the southerly winds that soon follow the appearance of the aurora on our coasts.

ON A NEW INVENTED STOVE.[1]

TO THE MARQUIS TURGOT.

Passy, 1*st May*, 1781.

I DID intend, when in London, to have pub-

[1] See Plate IV.

lished a pamphlet, describing the new stove you mention, and for that purpose had a plate engraved, of which I send you an impression. But I have since been too much engaged in affairs to execute that intention. Its principle is that of a siphon reversed, operating on air in a manner somewhat similar to the operation of the common siphon on water. The funnel of the chimney is the longer leg, the vase is the shorter: and, as in the common siphon, the weight of water in the longer leg is greater than that in the shorter leg; and thus in descending permits the water in the shorter leg to rise, by the pressure of the atmosphere; so in this aerial siphon, the levity of the air in the longer leg being greater than that in the shorter, it rises and permits the pressure of the atmosphere to force that in the shorter to descend. This causes the smoke to descend also, and in passing through burning coals, it is kindled into flame, thereby heating more the passages in the iron box whereon the vase which contains the coals is placed; and retarding at the same time the consumption of the coals. On the left hand of the engraving you see the machine put together and placed in a niche built for it in a common chimney. On the right hand the parts (except the vase) are shown separately. If you should desire a more particular explanation, I will give it to you *viva voce*, whenever you please. I think with you that it is capable of being used to advantage in our kitchens, if

one could overcome the repugnance of cooks to the using of new instruments and new methods.

With great respect, I have the honor to be, &c.

B. Franklin.

ON THE LONG RETENTION OF INFECTION IN DEAD BODIES AFTER SEPULTURE, &c.

To Mons. Vicq d'Azyr.

Sir, *Passy, July* 20, 1781.

I received the letter you some time since did me the honor of writing to me, accompanied with a number of the pieces that were distributed at the last public meeting of the Royal Society of Medicine. I shall take care to forward them to different parts of America, as desired. Be pleased to present my thanks to the society for the copy sent me of the curious and useful reports relating to the sepulture in the island of Malta. I should be glad of another copy, if it can be spared, being desirous of sending one to each of the philosophical societies in America.

With respect to the length of time during which the power of infection may be contained in dead bodies, which is considered in that report, I would mention to you three facts, which, though not all of equal importance or weight, yet methinks it may be well to preserve a memorandum of them, that such observations may be made when occasion

offers, as are proper to confirm or invalidate them.

While I resided in England, I read in a newspaper, that in a country village at the funeral of a woman whose husband had died of the small-pox 30 years before, and whose grave was dug so as to place her by his side, the neighbors attending the funeral were offended with the smell arising out of the grave, occasioned by a breach in the husband's old coffin, and 25 of them were in a few days taken ill with that distemper, which before was not in that village or its neighborhood, nor had been for the number of years above mentioned.

About the years 1763 or 1764, several physicians of London, who had been present from curiosity at the dissection of an Egyptian mummy, were soon after taken ill of a malignant fever, of which they died. Opinions were divided on this question. It was thought by some that the fever was caused by infection from the mummy; in which case the disease it died of must have been embalmed as well as the body. Others who considered the length of time, at least 2000 years, since that body died, and also that the embalming must be rather supposed to destroy the power of infection, imagined the illness of these gentlemen must have had another original.

About the year 1773, the captain of a ship which had been at the island of Teneriffe, brought from

thence the dried body of one of the ancient inhabitants of that island, which must have been at least 300 years old, that custom of drying the dead there having been so long discontinued. Two members of the Royal Society went to see that body. They were half an hour in a small close room with it, examining it very particularly. The next day they were both affected with a singularly violent *cold*,[1] attended with uncommon circumstances, which continued a long time. On comparing together the particulars of their disorder, they agreed in suspecting that possibly some effluvia from the body might have been the occasion of that disorder in them both: perhaps they were mistaken. But as we do not yet know with certainty how long the power of infection may in some bodies be retained, it seems well in such cases to be cautious till farther light shall be obtained.

I wish it were in my power to contribute more essentially in advancing the good work the society are so laudably engaged in. Perhaps some useful hints may be extracted from the enclosed paper of Mr. Small's.[2] It is submitted to your judgment; and if you should find any thing in it worthy of being communicated to the society, and of which extracts may be useful if printed in the

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[1] Cold is a general name given by the English to all sorts of rheums and catarrhs.

[2] See OF VENTILATION—*Writings*, Part IV.

memoirs, it will be a pleasure to me; who am, with great esteem and respect, sir, &c.

B. FRANKLIN.

P. S. July 24. Since writing the above, I have met with the following article in the *Courier de l'Europe* of the 13th inst. viz.

Extrait d'une lettre d'Edimbourg, en date du 30 Juin.

"J'apprends par une personne qui vient de Montrose, que la fièvre épidémique qui s'est manifestée il y a quelque tems dans le Méarns, désole encore aujourd'hui ce voisinage avec tant de violence qu'un de ses amis a été invité à assister à 15 enterremens dans un seul jour. On dit que cette maladie doit son origine à la folle curiosité de quelques paysans, qui, à la Chandeleur dernière, exhumèrent quelques personnes mortes de la peste dans le siècle précédent, et qu'on avoit enterrées dans le Moss de *Arnhalk*. Ce qui est arrivé à la famille de M. Robert Aikenhead est singulièrement malheureux: vers le milieu du mois dernier il a été attaqué de cette contagion, et elle s'est communiquée au reste de sa famille consistant en neuf personnes, dont deux sont mortes ainsi que lui, et le reste n'est pas sans danger."

[*Translation.*]

Extract of a letter from Edinburgh, dated June 30.

"I understand by a person just returned from

Montrose, that the epidemic fever which has made its appearance in the county of Mearns, ravages that neighborhood with such violence, that one of his friends was invited to attend fifteen funerals on the same day. It is said that this malady originated in the ill-judged curiosity of some country people, who, at Candlemas last, opened the graves of some persons who had died of the plague in the preceding century, and who had been buried in the Moss of Arnhall. The circumstances which have happened in the family of Mr. Robert Aikenhead are singularly unfortunate: about the middle of last month he took the infection, which was communicated to the rest of his family, consisting of nine persons; two of whom, together with himself, are dead, and the others not out of danger."

ON CONDUCTORS OF HEAT, &c.

To Dr. Ingenhausz.

Passy, Oct. 2, 1781.

It is a long time, my dear friend, since I have had the pleasure of writing to you. I have postponed it too often from a desire of writing a good deal on various subjects, which I could not find sufficient time to think of properly. Your experiments *on the conducting of heat* was one subject: the finishing my *remarks on the stroke of lightning*

in Italy[1] was another; then I was taken ill with a severe fit of the gout soon after you left us, which held me near three months, and put my business and correspondence so far behind-hand, that I was long in getting it up again. Add to this, that I find indolence increases with age, and that I have not near the activity I formerly had. But I cannot afford to lose your correspondence, in which I have always found so much pleasure and instruction: I now force myself to write, and I fancy this letter will be long.

I have now before me your several favors of Dec. 5, 1780, Feb. 7, April 7, May 23, and Aug. 29, 1781. I was glad to find by the first, that you enjoyed a good state of health, and that you had leisure to pursue your philosophical inquiries. I wish you that continued success which so much industry, sagacity, and exactness in making experiments, have a right to expect. You will have much immediate pleasure by that success, and in time great reputation. But for the present the reputation will be given grudgingly, and in as small a quantity as possible, mixed too with some mortification. One would think that a man so laboring disinterestedly for the good of his fellow-creatures, could not possibly by such means make himself enemies; but there are minds who cannot

[1] See—*Attempt to explain the effects of Lightning on the Steeple of Cremona.* WRITINGS, Part IV.

bear that another should distinguish himself even by greater usefulness; and though he demands no profit, nor any thing in return but the good-will of those he is serving, they will endeavor to deprive him of that, first by disputing the truth of his experiments, then their utility, and being defeated there, they finally dispute his right to them, and would give the credit of them to a man that lived 3000 years ago, or at 3000 leagues distance, rather than to a neighbor or even a friend. Go on, however, and never be discouraged. Others have met with the same treatment before you, and will after you. And whatever some may think and say, it is worth while to do men good, for the self-satisfaction one has in the reflection.

Your account of the experiments you made with the wires, gave me a great deal of pleasure: I have shown it to several persons here, who think it exceedingly curious. If you should ever repeat those experiments, I wish your attention to one circumstance. I think it possible, that in dipping them into the wax, and taking them out suddenly, the metal which attracts heat most readily, may chill and draw out with it a thicker coat of wax; and this thicker coat might, in the progress of the experiment, be longer melting. They should therefore be kept so long in the wax, as to be all well and equally heated. Perhaps you may thus find the progress of heat in the silver quicker and greater. I think, also, that if the hot oil in which

you dipped the ends was not stagnant, but in motion, the experiment would be more complete, because the wire which quickest diminishes the heat of the oil next to it, finds soonest the difficulty of getting more heat from the oil farther distant, which depends on the nature of the oil as a conductor of heat, that which is already cooled interfering between the hotter oil and the wire. In reversing the experiment also, to try which of the metals cools fastest, I think the wires should be dipped in *running* cold water; for when stagnant, the hot wires, by communicating heat to the water that is near them, will make it less capable of receiving more heat; and as the metals which communicate their heat most freely and readily will soonest warm the water round them, the operation of such metals may therefore soonest stop,—not because they naturally longer withhold their heat, but because the water near them is not in a state to receive it. I do not know that these hints are founded; I suggest them only as meriting a little consideration. Every one is surprised that the progress of the heat seems to have no connexion with the gravity or the levity of the metals.

B. FRANKLIN.

AN ACCOUNT OF TOADS

FOUND ENCLOSED IN THE SOLID OF A STONE QUARRY.

AT Passy, near Paris, April 6, 1782, being with M. De Chaumont, viewing his quarry, he mentioned to me, that the workmen had found a living toad shut up in the stone. On questioning one of them, he told us they had found four in different cells which had no communication: that they were very lively and active when set at liberty: that there was in each cell some loose, soft, yellowish earth, which appeared to be very moist. We asked, if he could show us the parts of the stone that formed the cells? He said no; for they were thrown among the rest of what was dug out, and he knew not where to find them. We asked, if there appeared any opening by which the animal could enter? He said, no, not the least. We asked if, in the course of his business as a laborer in quarries, he had often met with the like? He said, never before. We asked, if he could show us the toads? He said, he had thrown two of them up on a higher part of the quarry, but knew not what became of the others. He then came up to the place where he had thrown the two, and finding them, he took them by the foot, and threw them up to us, upon the ground where we stood. One of them was quite dead, and appeared very lean: the other was plump and still living. The

part of the rock where they were found, is at least fifteen feet below its surface, and is a kind of limestone. A part of it is filled with ancient sea shells, and other marine substances. If these animals have remained in this confinement since the formation of the rock, they are probably some thousands of years old. We have put them in spirits of wine, to preserve their bodies a little longer. The workmen have promised to call us if they meet with any more, that we may examine their situation. Before a suitable bottle could be found to receive them, that which was living when we first had them, appeared to be quite dead and motionless; but being in the bottle, and the spirits poured over them, he flounced about in it very vigorously for two or three minutes, and then expired.

It is observed that animals who perspire but little, can live long without food; such as tortoises, whose flesh is covered with a thick shell, and snakes, who are covered with scales, which are of so close a substance as scarcely to admit the passage of perspirable matter through them. Animals that have open pores all over the surface of their bodies, and live in air which takes off continually the perspirable part of their substance, naturally require a continual supply of food to maintain their bulk. Toads shut up in solid stone, which prevents their losing any thing of their substance, may perhaps for that reason need no sup-

ply; and being guarded against all accidents, and all the inclemencies of the air and changes of the seasons, are, it seems, subject to no diseases, and become as it were immortal. B. F.

[*The following copy of a letter from Sir John Pringle to Mr. A. Small, was annexed to the above account, in Dr. F.'s papers.*]

TO MR. SMALL.

SIR, *Minorca, April* 25, 1780.

Last year I had the honor to inform you, that two of those large moths called Muskitoe Hawks, which appear about September, and disappear about the beginning of December, lived 71 days after I had cut their heads off with a pair of scissars.

The last autumn I made the same experiment upon several, keeping them under separate glasses, in a closet, where there was no fire. The most of them lived different periods, from 3, to 60 and 70 days. Those which exceeded that number of days, were four, viz. one from the 30th of October to the 21st of January, 83 days; one from the 12th of December to the 21st of April, 131 days; and one from the 24th of October to the 15th of April, 174 days. As they are very active, and covered with a sort of plumage, which makes it difficult to cut their heads off, without bruising or otherwise injuring the body, I imagine that may partly be the reason of their living different periods; and if, after the operation, any glutinous liquor proceeded from the body, that moth would die soon.

I put several under glasses, without cutting off their heads, none of which lived many days.

I am, sir, with great esteem, your most obedient and most humble servant, (Signed) JOHN PRINGLE.

QUERIES ON ELECTRICITY,

From Dr. Ingenhausz; with Answers by Dr. Franklin.

Question 1.

If the electrical fluid is truly accumulated on the inside of a Leyden phial, and expelled in the same proportion from the other side, why are the particles of glass not all thrown outwards, when the phial being overcharged, breaks or is perforated by a spontaneous explosion?

Answer.

By the circumstances that have appeared to me, in all the jars that I have seen perforated at the time of their explosion, I have imagined that the charge did not pass by those perforations. Several single jars that have broke while I was charging them, have shown, besides the perforation in the body, a trace on both sides of the neck, where the polish of the glass was taken off the breadth of a straw; which proved that great part at least of the charge, probably all, had passed over that trace. I was once present at the discharge of a battery containing thirty jars, of which eight were perforated and spoilt at the time of the discharge, yet the effect of the charge on the bodies upon which it was intended to operate, did not appear to be diminished. Another time I was present

when twelve out of twenty jars were broken at the time of the discharge, yet the effect of the charge which passed in the regular circuit, was the same as it would have been if they had remained whole. Were those perforations an effect of the charge within the jar forcing itself through the glass to get at the outside, other difficulties would arise, and demand explanation. 1. How it happens that in eight bottles, and in twelve the strength to bear a strong charge should be so equal, that no one of them would break before the rest, and thereby save his fellows; but all should burst at the same instant? 2. How it happens that they bear the force of the great charge till the instant that an easier means of discharge is offered them, which they make use of, and yet the fluid breaks through at the same time?

My conjecture is, that there has been in the place where the rupture happens, some defect in the glass, some grain of sand perhaps, or some little bubble in the substance nearly void, where during the charging of the jar, the electric fluid forced in and confined till the pressure is suddenly taken off by the discharge, when not being able to escape so quickly, it bursts its way out by its elastic force. Hence all the ruptures happen nearly at the same instant with the regular discharge, though really a little posterior, not being themselves discharges, but the effects of a discharge which passed in another channel.

Question 2.

When a strong explosion is directed through a pack of cards or a book, having a piece of tin foil between several of its leaves, the electrical flash makes an impression in some of those metallic leaves, by which it seems as if the direction of the electric explosion had gone from the outside towards the inside, when on the other metallic leaves, the impression is in such a direction, that it indicates the current of electrical fire to have made its way from the inside of the phial towards the outside; so that it appears to some electricians, that in the time of the explosion of an electrical phial, two streams of electrical fire rush at the same time from both surfaces, and meet or cross one another.

Answer.

These impressions are not effects of a moving body, striking with force in the direction of its motion; they are made by the burrs rising in the neighboring perforated cards, which rise accidentally sometimes on one side of a card, sometimes on the other, in consequence of certain circumstances in the form of their substances or situations. In a single card, supported without touching others, while perforated by the passing fluid, the burr generally rises on both sides, as I once

shewed to Mr. Symmer at his house. I imagine that the hole is made by a fine thread of electric fluid first passing, and augmented to a bigger thread at the time of the explosion, which obliging the parts of a card to recede every way, condenses a part within the substance, and forces a part out on each side, because there is least resistance.

Question 3.

When a flash of lightning happens to hit a flat piece of metal, the metal has sometimes been pierced with several holes, whose edges were turned some the one way and some the other, so that it has appeared to some philosophers that several streams of electrical fire had rushed in one way, and some the opposite way. Such an effect of lightning has been published lately by Father Barletti.

Answer.

This will be answered in my remarks on Mr. Barletti's book; which remarks when finished, I will send you.

Question 4.

Though from the very charging of the Leyden phial, it seems clear, that the electrical fluid does in reality not pervade the substance of glass, yet it is still difficult to conceive how such a subtile fluid may be forced out from one side of a very thick

pane of glass, by a similar quantity of electrical fire thrown upon the other surface, and yet that it does not pass through any substance of glass, however thin, without breaking it. Is there some other fact or illustration besides those to be found in your public writings, by which it may be made more obvious to our understanding, that electrical fire does not enter at all the very substance of glass, and yet may force from the opposite surface an equal quantity; or that it really enters the pores of the glass without breaking it? Is there any comparative illustration or example in nature, by which it may be made clear, that a fluid thrown upon one surface of any body, may force out the same fluid from the other surface without passing through the substance?

Answer.

That the electric fluid, by its repulsive nature, is capable of forcing portions of the same fluid out of bodies without entering them itself, appears from this experiment. Approach an isolated body with a rubbed tube of glass; the side next the tube will then be electrised negatively, the opposite positively. If a pair of cork balls hang from that opposite side, the electrical fluid forced out of the body will appear in those balls, causing them to diverge. Touch that opposite side, and you thereby take away the positive electricity. Then remove the tube, and you leave the body all in a

negative state. Hence it appears, that the electric fluid appertaining to the glass tube did not enter the body, but retired with the tube, otherwise it would have supplied the body with the electricity it had lost.

With regard to *powder magazines*, my idea is, that to prevent the mischief which might be occasioned by the stones of their walls flying about in case of accidental explosion, they should be constructed in the ground; that the walls should be lined with lead, the floor lead, all a quarter inch thick, and the joints well soldered; the cover copper, with a little scuttle, to enter the whole in the form of a canister for tea. If the edges of the cover-scuttle fall into a copper channel containing mercury, not the smallest particle of air or moisture can enter to the powder, even though the walls stood in water, or the whole was under water.

ON THE THEORY OF THE EARTH, AND ITS MAGNETISM.

TO THE ABBE SOULAVIE.

[Occasioned by his sending me some notes he had taken of what I had said to him in conversation on the Theory of the Earth, and written to set him right in some points wherein he had mistaken my meaning.] B. F.

SIR, *Passy, September* 22, 1782.

I return the papers with some corrections. I did not find coal mines under the calcareous rock

in Derbyshire. I only remarked, that at the lowest part of that rocky mountain which was in sight, there were oyster shells mixed in the stone; and part of the high county of Derby being probably as much above the level of the sea, as the coal mines of Whitehaven, were below it, it seemed a proof that there had been a great *boulversement* in the surface of that island, some part of it having been depressed under the sea, and other parts, which had been under it, being raised above it. Such changes in the superficial parts of the globe, seemed to me unlikely to happen, if the earth were solid to the centre. I therefore imagined, that the internal parts might be a fluid more dense, and of greater specific gravity than any of the solids we are acquainted with, which therefore might swim in or upon that fluid. Thus the surface of the globe would be a shell, capable of being broken and disordered by the violent movements of the fluid on which it rested. And as air has been compressed by art so as to be twice as dense as water, in which case, if such air and water could be contained in a strong glass vessel, the air would be seen to take the lowest place, and the water to float above and upon it; and as we know not yet the degree of density to which air may be compressed, and M. Amontons calculated, that its density increasing as it approached the centre, in the same proportion as above the surface, it would at the depth of leagues be heavier than gold; possibly the dense

fluid occupying the internal parts of the globe might be air-compressed. And as the force of expansion in dense air when heated, is in proportion to its density, this central air might afford another agent to move the surface, as well as be of use in keeping alive the subterraneous fires; though, as you observe, the sudden rarefaction of water coming into contact without those fires, may also be an agent sufficiently strong for that purpose, when acting between the incumbent earth and the fluid on which it rests.

If one might indulge imagination in supposing how such a globe was formed, I should conceive, that all the elements in separate particles being originally mixed in confusion, and occupying a great space, they would (as soon as the Almighty fiat ordained gravity, or the mutual attraction of certain parts, and the mutual repulsion of others, to exist) all move to their common centre: that the air being a fluid whose parts repel each other, though drawn to the common centre by their gravity, would be densest towards the centre, and rarer as more remote; consequently all matters lighter than the central parts of that air, and immersed in it, would recede from the centre, and rise till they arrived at that region of the air which was of the same specific gravity with themselves, where they would rest; while other matter, mixed with the lighter air, would descend, and the two meeting, would form the shell of the first earth,

leaving the upper atmosphere nearly clear. The original movement of the parts towards their common centre would naturally form a whirl there; which would continue upon the turning of the new-formed globe upon its axis, and the greatest diameter of the shell would be in its equator. If by any accident afterwards the axis should be changed, the dense internal fluid, by altering its form, must burst the shell, and throw all its substance into the confusion in which we find it. I will not trouble you at present with my fancies concerning the manner of forming the rest of our system. Superior beings smile at our theories, and at our presumption in making them. I will just mention, that your observation of the ferruginous nature of the lava which is thrown out from the depths of our volcanos, gave me great pleasure. It has long been a supposition of mine that the iron contained in the surface of the globe has made it capable of becoming, as it is, a great magnet; that the fluid of magnetism perhaps exists in all space; so that there is a magnetical north and south of the universe, as well as of this globe, and that if it were possible for a man to fly from star to star, he might govern his course by the compass; that it was by the power of this general magnetism this globe became a particular magnet. In soft or hot iron the fluid of magnetism is naturally diffused

equally; when within the influence of the magnet, it is drawn to one end of the iron, made denser there and rarer at the other. While the iron continues soft and hot, it is only a temporary magnet; if it cools or grows hard in that situation, it becomes a permanent one, the magnetic fluid not easily resuming its equilibrium. Perhaps it may be owing to the permanent magnetism of this globe, which it had not at first, that its axis is at present kept parallel to itself, and not liable to the changes it formerly suffered, which occasioned the rupture of its shell, the submersions and emersions of its lands, and the confusion of its seasons. The present polar and equatorial diameters differing from each other near ten leagues, it is easy to conceive, in case some power should shift the axis gradually, and place it in the present equator, and make the new equator pass through the present poles, what a sinking of the waters would happen in the present equatorial regions, and what a rising in the present polar regions; so that vast tracts would be discovered that now are under water, and others covered, that are now dry, the water rising and sinking in the different extremes near five leagues. Such an operation as this possibly occasioned much of Europe, and among the rest this Mountain of Passy on which I live, and which is composed of limestone, rock and sea-shells, to be abandoned by the sea, and to change its ancient climate, which seems to have been a hot one. The

globe being now become a perfect magnet, we are, perhaps, safe from any change of its axis. But we are still subject to the accidents on the surface, which are occasioned by a wave in the internal ponderous fluid; and such a wave is producible by the sudden violent explosion you mention, happening from the junction of water and fire under the earth, which not only lifts the incumbent earth that is over the explosion, but impressing with the same force the fluid under it, creates a wave, that may run a thousand leagues, lifting, and thereby shaking, successively, all the countries under which it passes. I know not, whether I have expressed myself so clearly, as not to get out of your sight in these reveries. If they occasion any new inquiries, and produce a better hypothesis, they will not be quite useless. You see I have given a loose to imagination; but I approve much more your method of philosophising, which proceeds upon actual observation, makes a collection of facts, and concludes no further than those facts will warrant. In my present circumstances, that mode of studying the nature of the globe is out of my power, and therefore I have permitted myself to wander a little in the wilds of fancy. With great esteem, I have the honor to be, sir, &c.

B. FRANKLIN.

P. S. I have heard, that chemists can by their art decompose stone and wood, extracting a consi-

derable quantity of water from the one, and air from the other. It seems natural to conclude from this, that water and air were ingredients in their original composition: for men cannot make new matter of any kind. In the same manner may we not suppose, that when we consume combustibles of all kinds, and produce heat or light, we do not create that heat or light; but only decompose a substance, which received it originally as a part of its composition? Heat may be thus considered as originally in a fluid state; but attracted by organised bodies in their growth, becomes a part of the solid. Besides this, I can conceive, that in the first assemblage of the particles of which this earth is composed, each brought its portion of the loose heat that had been connected with it, and the whole, when pressed together, produced the internal fire that still subsists.

ON AN ELECTRICAL EXPERIMENT.

TO DR. INGENHAUSZ.

Passy, May 16, 1783.

I AM glad you have made the experiments you mention, and with success. You will find that the holes are not made by the impulse of the fluid moving in certain directions, but by circumstances of explosion of parts of the matter; and I still think my explanation of the holes in the vane pro-

bable, viz. that it was the explosion of tin against parts of the copper-plate that were almost in a state of fusion, and therefore easily burst through either on one side or the other, as it happened. The bursting of the 12 bottles all at once, I take to be owing to small bubbles in the substance of the glass, or grains of sand, into which a quantity of the electric fluid had been forced and compressed while the bottles were charging; and when the pressure was suddenly taken off by discharging the bottles, that confined portion by its elastic force expanding caused the breach. My reasons for thinking that the charge did not pass by those holes you will find in a former letter; and I think you will always find that the coating within and without is forced both ways by the explosion of these bubbles.

B. FRANKLIN.



ON THE SHOCK BY THE ELECTRIC BOTTLE, AND THE DENSITY OF GLASS.

TO * * * *.

SIR, *Passy, June* 14, 1783.

I RECEIVED some time since the letter you honored me with, containing your hypothesis for explaining the shock given by the electric bottle, on which you seem to desire my opinion. It is many years since I was engaged in those pleasing studies, and my mind is at present too much occupied

with other and more important affairs to permit my returning to them. I cannot therefore examine your ingenious hypothesis with the attention it appears to merit. You will find in a letter of mine to Dr. Lining, dated March 18, 1775, that I abandoned my hypothesis of the greater density of glass in the middle than near its surfaces, as contributing to produce the effect, because I found the effect to be the same after I had ground that part away. And I think you might likewise try yours by an easy experiment. Take a plate of lead twelve inches square, cover one of its sides with a coat of bees' wax about one line thick; upon that apply closely a thin plate of lead eight inches square, so as to leave a margin of two inches all round. Electrify this composition of lead and wax, and try if you can receive a shock from it; if not, you may draw thence a further argument to support your hypothesis, because the wax, though a non-conductor, is not elastic, any more than pure lead. I see you are endowed with a genius for the study of nature, and I would recommend it to you to employ your time rather in making experiments than in making hypothesis and forming imaginary systems, which we are all too apt to please ourselves with till some experiment comes, and unluckily destroys them. Wishing you success in your inquiries, I have the honor to be, sir, &c.

F. FRANKLIN.

To Mr. Edward Nairne.

On his Patent Electrical Machine, and the Effects of Lightning on the Eyes, &c. of Animals killed by it.

Dear Sir, *Passy, Oct.* 18, 1783.

I received your favor of August 14, by Mr. Sykes, with the book of directions for using your patent electric machine. The machine itself is also come to hand in good order, after some delay on the road; and I think it very ingeniously contrived indeed: I wish your success in the sale may be equal to its merits. The experiments in your pamphlet gave me pleasure, and I shall be glad to see the account you mention of the shortening of wires by lightning.

What you have heard of the eyes of sheep forced out by a stroke of lightning which killed them, puts me in mind of having formerly seen at Philadelphia six horses all killed by lightning in a stable, every one of whom appeared to have bled at the eyes, nose, and mouth; though I do not recollect that any of their eyes were out.

You are so good as to consider how much my time has been taken up, and to excuse on that account my being a bad correspondent. Near three years ago I began a letter to you on the subject of hygrometers. I had written three folio pages of it when I was interrupted by some business; and before I had time to finish it I had mislaid it. I

have now found it, and having added what I suppose I had intended to add, I enclose it. You can judge better than myself whether my idea of such an instrument is practicable and may be useful.

If you favor me with another line, let me know how Mrs. Nairne does, and your amiable children. With great esteem, &c. I am, B. FRANKLIN.

[*Enclosed in the foregoing.*]

PROPOSAL FOR A SLOWLY SENSIBLE HYGROMETER FOR CERTAIN PURPOSES.

TO MR. NAIRNE.

SIR, *Passy, near Paris, Nov.* 13, 1780.

THE qualities hitherto sought in an hygrometer, or instrument to discover the degree of moisture and dryness in the air, seems to have been an aptitude to receive humidity readily from a moist air, and to part with it as readily to a dry air. Different substances have been found to possess more or less of this quality; but when we shall have found the substance that has it in the greatest perfection, there will still remain some uncertainty in the conclusions to be drawn from the degree shown by the instrument, arising from the actual state of the instrument itself as to heat and cold. Thus if two bottles or vessels of glass or metal being filled, the one with cold, the other with hot water, are brought into a room, the moisture of the air in the

room will attach itself in quantities to the surface of the cold vessel, while if you actually wet the surface of the hot vessel, the moisture will immediately quit it, and be absorbed by the same air. And thus in a sudden change of the air from cold to warm, the instrument remaining longer cold may condense and absorb more moisture and mark the air as having become more humid, than it is in reality; and the contrary is a change from warm to cold.

But if such a suddenly changing instrument could be free from those imperfections, yet when the design is to discover the different degrees of humidity in the air of different countries, I apprehend the quick sensibility of the instrument to be rather a disadvantage; since to draw the desired conclusions from it, a constant and frequent observation day and night in each country will be necessary for a year or years, and the mean of each set of observations is to be found and determined. After all which, some uncertainty will remain respecting the different degrees of exactitude with which different persons may have made and taken notes of their observations.

For these reasons I apprehend that a substance though capable of being distended by moisture and contracted by dryness, is so slow in receiving and parting with its humidity, that the frequent changes in the atmosphere have not time to effect it sensibly, and which therefore should gradually take

nearly the medium of all those changes and preserve it constantly, would be the most proper substance of which to make such an hygrometer.

Such an instrument you, my dear sir, though without intending it, have made for me; and I, without desiring or expecting it, have received from you. It is therefore with propriety that I address to you the following account of it, and the more as you have both a head to contrive and a hand to execute the means of perfecting it. And I do this with greater pleasure, as it affords me the opportunity of renewing that ancient correspondence and acquaintance with you, which to me was always so pleasing and so instructive.

You may possibly remember that in or about the year 1758, you made for me a set of artificial magnets, six in number, each 5½ inches long, ½ an inch broad, and ⅙ of an inch thick. These with two pieces of soft iron, which together equalled one of the magnets, were enclosed in a little box of mahogany wood, the grain of which ran with, and not across the length of the box, and the box was closed by a little shutter of the same wood, the grain of which ran *across* the box, and the ends of this shutting piece were bevelled so as to fit and slide in a kind of dovetail groove when the box was to be shut or opened.

I have been of opinion that good mahogany wood was not affected by moisture so as to change its dimensions, and that it was always to be found

as the tools of the workmen left it. Indeed the difference at different times in the same country is so small as to be scarcely in a common way observable. Hence the box which was made so as to allow sufficient room for the magnets to slide in and out freely, and when in afforded them so much play that by shaking the box one could make them strike the opposite sides of the box alternately, continued in the same state all the time I remained in England, which was four years, without any apparent alteration. I left England in August 1762, and arrived at Philadelphia in October the same year. In a few weeks after my arrival, being desirous of showing your magnets to a philosophical friend, I found them so tight in the box, that it was with difficulty that I got them out, and constantly during the two years I remained there, viz. till November 1764, the difficulty of getting them out and in continued. The little shutter too, as wood does not shrink lengthways of the grain, was found too long to enter its grooves, and not being used was mislaid and lost, and I afterwards had another made that fitted.

In December 1764, I returned to England, and after some time I observed that my box was become full big enough for my magnets, and too wide for my new shutter; which was so much too short for its grooves, that it was apt to fall out; and to make it keep in, I lengthened it by adding to each end a little coat of sealing-wax.

I continued in England more than ten years, and during that time, after the first change, I perceived no alteration. The magnets had the same freedom in their box, and the little shutter continued with the added sealing-wax to fit its grooves, till some weeks after my second return to America.

As I could not imagine any other cause for this change of dimensions in the box when in the different countries, I concluded first generally that the air of England was moister than that of America. And this I supposed the effect of its being an island, where every wind that blows must necessarily pass over some sea before it arrived, and of course lick up some vapor. I afterwards indeed doubted whether I had not been too general in my conclusion; and whether it might not be just only so far as related to the city of London, where I resided; because there are many causes of moisture in the city air, which do not exist to the same degree in the country; such as the brewers' and dyers' boiling cauldrons, and the great number of pots and tea-kettles continually on the fire, sending forth abundance of vapor; and also the number of animals who by their breath constantly increase it; to which may be added that even the vast quantity of sea-coals burnt there, in kindling discharge a great deal of moisture.

When I was in England the last time, you also made for me a little achromatic pocket telescope. The body was brass, and it had a round case (I

think of thin wood) covered with shagreen. All the while I remained in England, though possibly there might be some small changes in the dimensions of this case, I neither perceived nor suspected any. There was always comfortable room for the telescope to slip in and out. But soon after I arrived in America, which was in May, 1775, the case became too small for the instrument, it was with much difficulty and various contrivances that I got it out, and I could never after get it in again during my stay there, which was eighteen months. I brought it with me to Europe, but left the case as useless, imagining that I should find the continental air of France as dry as that of Pennsylvania, where my magnet-box had also returned a second time to its narrowness, and pinched the pieces as heretofere, obliging me, too, to scrape the sealing-wax off the ends of the shutter.

I had not been long in France before I was surprised to find that my box was become as large as it had always been in England, the magnets entered and came out with the same freedom; and when in I could rattle them against its sides; this has continued to be the case without sensible variation. My habitation is out of Paris, distant almost a league, so that the moist air of the city cannot be supposed to have much effect upon the box: and I am on a high dry hill, as likely to be dry as any air in France. Whence it seems probable, that the air of England in general may, as well as that of

London, be moister than the air of America, since that of France is so, and in a part so distant from the sea.

The greater dryness of the air in America appears from some other observations. The cabinet-work formerly sent us from London, which consisted in thin plates of fine wood, glued upon fir, never would stand with us, the veneering, as those plates are called, would get loose and come off; both woods shrinking, and their grains often crossing, they were for ever cracking and flying. And in my electrical experiments there, it was remarkable, that a mahogany table on which my jars stood under the prime conductor to be charged, would often be so dry, particularly when the wind had been some time at N.W., which with us is a very drying wind, as to isolate the jars, and prevent their being charged till I had formed a communication between their coatings and the earth. I had a like table in London, which I used for the same purpose all the time I resided there; but it was never so dry as to refuse conducting the electricity.

Now what I beg leave to recommend to you is, that you would recollect, if you can, the species of mahogany of which you made my box, for you know there is a great deal of difference in woods that go under that name; or if that cannot be, that you would take a number of pieces of the finest and closest-grained mahogany that you can meet with, plane them to the thinness of about a line,

and the width of about two inches across the grain; and fix each of the pieces in some instrument that you can contrive, which will permit them to contract and dilate, and will show in sensible degrees by a moveable hand upon a marked scale, the otherwise less sensible quantities of such contraction and dilatation. If these instruments are all kept in the same place while making, and are graduated together while subject to the same degrees of moisture or dryness, I apprehend you will have so many comparable hygrometers, which being sent into different countries, and continued there for some time, will find and show there the mean of the different dryness and moisture of the air of those countries; and that with much less trouble than by any other hygrometer hitherto in use.

With great esteem, I am, dear sir, your most obedient and most humble servant,

B. FRANKLIN.

ON THE COMET SEEN IN YORKSHIRE, 1783.

TO MR. RITTENHAUSE, PHILADELPHIA.

SIR, *Passy, Dec.* 15, 1783.

ALL astronomical news that I receive, I think it my duty to communicate to you. The following is just come to hand, in a letter from the President of the Royal Society, dated at London the 9th instant.

" A miserable comet made its appearance to Mr. Nathan Pigot, in his observatory at Yorkshire, on the 19th past, and the weather has been so hazy in the evenings that it has scarce been observed since. It was on the 19th

	h.	m.	Right Ascen.	North Dec.
" at	11	15	41 0 0	3° 10′
" On the 20th	10	54	40 0 0	4 32

" On the 21st it was seen in the place where it was expected; but the night was too hazy to observe it.

" It appears like a nebula, with a diameter of about two minutes of a degree; the nucleus faint. It is seen with difficulty when the wires of the instrument are illuminated, but is not visible with an open glass."—Mr. Pigot.

" Nov. 29th. It was seen near the chin of Aries, and appeared like a nebulous star: as there was some moon-light, it was difficult to find it.

" Dec. 1st. It was removed near the preceding eye of Aries; but conceiving other astronomers, who had fixed instruments, have noted its place, he has not calculated the distance from any known star." —Mr. Herschell.

With great esteem, I have the honor to be, &c.

B. FRANKLIN.

ON BALLOONS, AND THEIR PROBABLE IMPORTANCE.

TO DR. INGENHAUSZ.

DEAR FRIEND, *Passy, Jan.* 16, 1784.

I HAVE this day received your favor of the 2d instant. Every information in my power respecting the balloons I sent you just before Christmas, contained in copies of my letters to Sir Joseph Banks. There is no secret in the affair, and I make no doubt that a person coming from you would easily obtain a sight of the different balloons of Mongolfier and Charles, with all the instructions wanted: and if you undertake to make one, I think it extremely proper and necessary to send an ingenious man here for that purpose; otherwise, for want of attention to some particular circumstance, or of not being acquainted with it, the experiment might miscarry, which, in an affair of so much public expectation, would have bad consequences, draw upon you a great deal of censure, and affect your reputation. It is a serious thing to draw out from their affairs all the inhabitants of a great city and its environs, and a disappointment makes them angry. At Bourdeaux, lately, a person who pretended to send up a balloon, and had received money from many people, not being able to make it rise, the populace were so exasperated that they pulled down his house, and had like to have killed him.

It appears, as you observe, to be a discovery of great importance, and what may possibly give a new turn to human affairs. Convincing sovereigns of the folly of wars, may perhaps be one effect of it; since it will be impracticable for the most potent of them to guard his dominions. Five thousand balloons capable of raising two men each could not cost more than five ships of the line: and where is the prince who can afford so to cover his country with troops for its defence, as that ten thousand men descending from the clouds might not in many places do an infinite deal of mischief, before a force could be brought together to repel them? It is a pity that any natural jealousy should, as you imagine it may, have prevented the English from prosecuting the experiment, since they are such ingenious mechanicians, that in their hands it might have made a more rapid progress towards perfection, and all the utility it is capable of affording. The balloon of Messrs. Charles and Robert was really filled with inflammable air. The quantity being great, it was expensive, and tedious filling, requiring two or three days and nights constant labor. It had a *soupape*, or valve, near the top, which they could open by pulling a string, and thereby let out some air when they had a mind to descend; and they discharged some of their ballast of sand when they would rise again. A great deal of air must have been let out when they landed, so that the loose part might envelope

one of them; yet the car being lightened by that one getting out of it, there was enough left to carry up the other rapidly. They had no fire with them. That is used only in M. Mongolfier's globe, which is open at bottom, and straw constantly burnt to keep it up. This kind is sooner and cheaper filled; but must be of much greater dimensions to carry up the same weight; since air rarefied by heat is only twice as light as common air, and inflammable air ten times lighter. Mons. Morveau, a famous chemist at Dijon, has discovered an inflammable air that will cost only a 25th part of the price of what is made by oil of vitriol poured on iron filings. They say it is made from sea-coal. Its comparative weight is not mentioned. I am as ever, my dear friend, yours most affectionately, B. FRANKLIN.

ON FIRE.

TO B. VAUGHAN.

MY DEAR FRIEND, *Passy, April 29*, 1784.

I RECEIVED your kind letters of the 16th and 20th instant. I thank you for your philosophical news. We have none here. I see your philosophers are in the way of finding out at last what fire is. I have long been of opinion that it exists everywhere in the state of a subtile fluid. That too much of that fluid in our flesh gives us the sensation we call heat; too little, cold. Its vibra-

tions, light. That all solid or fluid substances which are inflammable have been composed of it; their dissolution in returning to their original fluid state, we call fire. This subtile fluid is attracted by plants and animals in their growth, and consolidated. Is attracted by other substances, thermometers, &c. &c., variously; has a particular affinity with water, and will quit many other bodies to attach itself to water, and go off with it in evaporation. Adieu. Yours most sincerely,

B. F.

METEOROLOGICAL IMAGINATIONS AND CONJECTURES.

May, 1784.

THERE seems to be a region high in the air over all countries, where it is always winter, where frost exists continually; since in the midst of summer on the surface of the earth ice falls often from above, in the form of hail.

Hail-stones of the great weight we sometimes find them, did not probably acquire their magnitude before they began to descend. The air being 400 times rarer than water, is unable to support it but in the shape of vapor, a state in which its particles are separated. As soon as they are condensed by the cold of the upper regions so as to form a drop, that drop begins to fall. If it freezes into a grain of ice, that ice descends. In descend-

ing, both the drop of water and the grain of ice are augmented by particles of the vapor they pass through in falling, and which they condense by their coldness, and attach to themselves.

It is possible that in summer, much of what is rain when it arrives at the surface of the earth, might have been snow when it began its descent; but, being thawed in passing through the warm air near that surface, is changed from snow into rain.

How immensely cold must be the original particle of hail, which forms the centre of the future hail-stone, since it is capable of communicating sufficient cold, if I may so speak,[1] to freeze all the mass of vapor condensed round it, and form a lump of perhaps six or eight ounces in weight!

When in summer-time the sun is high, and long every day above the horizon, his rays strike the earth more directly and with longer continuance than in winter; hence the surface is more heated, and to a greater depth, by the effect of those rays.

When rain falls on the heated earth, and soaks down into it, it carries down with it a great part of the heat, which by that means descends still deeper.

The mass of earth, to the depth perhaps of 30

[1] *If I may so speak*, because perhaps it is not by communicating cold to the particles of vapor that it freezes them, but by depriving them of their heat.

feet, being thus heated to a certain degree, continues to retain its heat for some time. Thus the first snows that fall in the beginning of winter, seldom lie long on the surface, but are soon melted and absorbed. After which, the winds that blow over the country on which the snows had fallen, are not rendered so cold as they would have been by those snows, if they had remained. The earth, too, thus uncovered by the snow, which would have reflected the sun's rays, now absorbs them, receiving and retaining the warmth they afford. And thus the approach of the severity of winter is retarded; and the extreme degree of its cold is not always at the time we might expect it, viz. when the sun is at his greatest distance and the days the shortest, but some time after that period, according to the English proverb, which says,

As the day lengthens,
The cold strengthens;

the causes of refrigeration continuing to operate, while the sun returns too slowly, and his force continues too weak, to counteract them.

During several of the summer months of the year 1783, when the effect of the sun's rays to heat the earth in these northern regions should have been greatest, there existed a constant fog over all Europe. This fog was of a permanent nature; it was dry, and the rays of the sun seemed to have little effect towards dissipating it, as they easily do a moist fog arising from water. They

were indeed rendered so faint in passing through it, that when collected in the focus of a burning-glass they would scarce kindle brown paper; of course their summer effect in heating the earth was exceedingly diminished.

Hence the surface was early frozen.

Hence the first snows remained on it unmelted, and received continual additions.

Hence the air was more chilled, and the winds more severely cold.

Hence perhaps the winter of 1783-4 was more severe than any that had happened for many years.

The cause of this universal fog is not yet ascertained. Whether it was adventitious to this earth, and merely a smoke proceeding from the consumption by fire of some of those great burning balls or globes which we happen to meet with in our rapid course round the sun, and which are sometimes seen to kindle and be destroyed in passing our atmosphere, and whose smoke might be attracted and retained by our earth; or, whether it was the vast quantity of smoke long continuing to issue during the summer from Hecla in Iceland, and that other volcano which arose out of the sea near that island, which smoke might be spread by various winds over the northern part of the world, is yet uncertain.

It seems, however, worth the inquiry, whether other hard winters recorded in history, were preceded by similar permanent and widely-extended

summer fogs. Because, if found to be so, men might from such fogs conjecture the probability of a succeeding hard winter, and of the damages to be expected by the breaking up of frozen rivers at the approach of spring, and take such measures as are possible and practicable to secure themselves and effects from the mischiefs that attended the last.

PHYSICAL AND METEOROLOGICAL CONJECTURES, OBSERVATIONS AND SUPPOSITIONS. 1756.

The particles of air are kept at a distance from each other by their mutual repulsion.

Even these particles mutually and equally repelling each other, must form an equilateral triangle.

All the particles of air gravitate towards the earth, which gravitation compresses them, and shortens the sides of the triangles: otherwise their mutual repellency would force them to greater distances from each other.

Whatever particles of other matter (not endued with that repellency) are supported in air, must adhere to the particles of air, and be supported by them; for in the vacancies there is nothing they can rest on.

Air and water mutually attract each other. Hence water will dissolve in air, as salt in water.

The specific gravity of matter is not altered by

dividing the matter, though the superficies may be increased. Sixteen leaden bullets of an ounce each, weigh as much in water as one of a pound, whose superficies is less.

Therefore the supporting of salt in water is not owing to its superficies being increased.

A lump of salt, though laid at rest at the bottom of a vessel of water, will dissolve therein, and its parts move every way till equally diffused in the water; therefore there is a mutual attraction between water and salt. Every particle of water assumes as many of salt as can adhere to it; when more is added, it precipitates and will not remain suspended.

Part of a fluid having more of what it dissolves, will communicate to other parts that have less. This very salt water coming in contact with fresh, communicates its saltness till all is equal, and the sooner if there is but a little motion of the water. Even earth will dissolve and mix with air. A stroke of a horse's hoof in a hot dusty road, will raise a cloud of dust, that shall expand every way till perhaps near as big as a common house. 'Tis not by mechanical motion communicated to the particles of dust, by the hoof, that they fly so far, nor by the wind that they spread wide: but the air near the ground more heated by the hot dust struck into it is rarefied and rises, and in rising mixes with cooler air, and communicates of its dust to it, and 'tis at length so diffused as to

become invisible. Quantities of dust are thus carried up in dry seasons; showers wash it from the air, and bring it down again. For water attracting it stronger, it quits the air and adheres to the water.

Air suffering continual changes in the degrees of its heat, from various causes and circumstances, and consequently changes in its specific gravity, must therefore be in continual motion.

Water in the same manner will dissolve in air, every particle of air assuming one or more particles of water; when too much is added, it precipitates in rain.

But there not being the same contiguity between the particles of air as of water, the solution of water in air is not carried on without a motion of the air, so as to cause a fresh accession of dry particles.

A small quantity of fire mixed with water, or degree of heat therein, so weakens the cohesion of its particles, that those on the surface easily quit it, and adhere to the particles of air.

A greater degree of heat is required to break the cohesion between water and air.

Air moderately heated will support a greater quantity of water invisibly than cold air; for its particles being by heat repelled to a greater distance from each other, thereby more easily keep the particles of water that are annexed to them from running into cohesions that would obstruct, reflect, or refract the light.

Hence when we breathe in warm air, though the same quantity of moisture may be taken up from the lungs as when we breathe in cold air, yet that moisture is not so visible.

Water being extremely heated, i. e. to the degree of boiling, the particles in quitting it so repel each other as to take up vastly more space than before, and by that repellency support themselves, expelling air from the space they occupy. That degree of heat being lessened, they again mutually attract, and having no air-particles mixed to adhere to, by which they might be supported and kept at a distance, they instantly fall, coalesce, and become water again.

The water commonly diffused in our atmosphere, receives such a degree of heat from the sun or otherwise, as water has when boiling; it is not therefore supported by such heat, but by adhering to air.

Water being dissolved in and adhering to air, that air will not readily take up oil, because of the natural repellency between water and oil.

Hence oils evaporate but slowly, the air having generally a quantity of dissolved water.

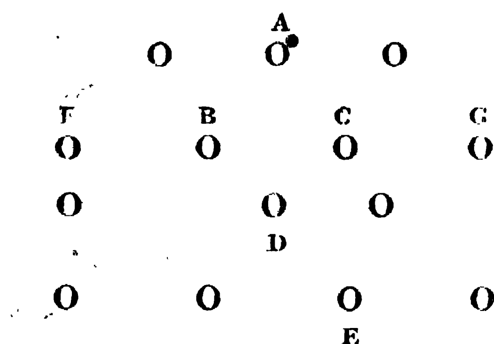
Oil being heated extremely, the air that approaches its surface will be also heated extremely; the water then quitting it, it will attract and carry off oil which can now adhere to it. Hence the quick evaporation of oil heated to a degree.

Oil being dissolved in air, the particles to which it adheres will not take up water.

Hence the suffocating nature of air impregnated with burnt grease, as from snuffs of candles and the like. A certain quantity of moisture should be every moment discharged and taken away from the lungs; air that has been frequently breathed, is already overloaded, and for that reason can take no more, so will not answer the end. Greasy air refuses to touch it. In both cases suffocation for want of the discharge.

As air will attract and support many other substances, a particle of air loaded with adhering water, or any other matter, is heavier than before, and would descend.

The atmosphere supposed at rest, a loaded descending particle must act with a force on the particles it passes between or meets with, sufficient to overcome in some degree their mutual repellency, and push them nearer to each other.



Thus, supposing the particles A B C D, and the others near them, to be at the distance caused by their mutual repellency, (confined by their common gravity,) if A would descend to E, it must pass

between B and C: when it comes between B and C, it will be nearer to them than before, and must either have pushed them nearer to F and G, contrary to their mutual repellency, or press through by a force exceeding its repellency with them. It then approaches D, and to move it out of the way must act on it with a force sufficient to overcome its repellency with the two next lower particles by which it is kept in its present situation. Every particle of air, therefore, will bear any load inferior to the force of these repulsions.

Hence the support of fogs, mists, clouds.

Very warm air clear, though supporting a very great quantity of moisture, will grow turbid and cloudy on the mixture of a colder air; as foggy air will grow clear by warming.

Thus the sun shining on a morning fog, dissipates it. Clouds are seen to waste in a sunshiny day.

But cold condenses and renders visible the vapor. A tankard or decanter filled with cold water, will condense the moisture of warm clear air on its outside, where it becomes visible as dew, coalesces into drops, and descends in little streams.

The sun heats the air of our atmosphere most near the surface of the earth; for there, besides the direct rays, there are many reflections. Moreover, the earth itself being heated, communicates of its heat to the neighboring air.

The higher regions having only the direct rays

of the sun passing through them, are comparatively very cold. Hence the cold air on the tops of mountains, and snow on some of them all the year, even in the torrid zone. Hence hail in summer.

If the atmosphere were all of it both above and below, always of the same temperature as to cold or heat, then the upper air would always be *rarer* than the lower, because the pressure on it is less; consequently lighter, and therefore would keep its place.

But the upper air may be more condensed by cold than the lower air by pressure, the lower more expanded by heat than the upper for want of pressure. In such case the upper air will become the heavier, the lower the lighter.

The lower region of air being heated and expanded, heaves up and supports for some time the colder heavier air above, and will continue to support it while the equilibrium is kept. Thus water is supported in an inverted open glass, while the equilibrium is maintained by the equal pressure upwards of the air below; but the equilibrium by any means breaking, the water descends on the heaviest side, and the air rises into its place.

The lifted heavy cold air over a heated country, becoming by any means unequally supported, or unequal in its weight, the heaviest part descends first, and the rest follows impetuously; hence gusts after heats, and hurricanes in hot climates. Hence

the air of gusts and hurricanes cold though in hot climes and seasons, it coming from above.

The cold air descending from above, as it penetrates our warm region full of watery particles, condenses them, renders them visible, forms a cloud, thick and dark, overcasting sometimes at once large and extensively; sometimes when seen at a distance small at first, gradually increasing, the cold edge or surface of the cloud condensing the vapors next it, which form smaller clouds that join it, increase its bulk, it descends with the wind, and its acquired weight, draws nearer the earth, grows denser with continual additions of water, and discharges heavy showers.

Small black clouds thus appearing in a clear sky in hot climates, portend storms, and warn seamen to hand their sails.

The earth turning on its axis in about twenty-four hours, the equatorial parts must move about fifteen miles in each minute; in northern and southern latitudes this motion is gradually less to the poles, and there nothing.

If there was a general calm over the face of the earth, it must be by the airs moving in every part as fast as the earth or sea it covers.

He that sails or rides has insensibly the same degree of motion as the ship or coach with which he is connected. If the ship strikes the shore, or the coach stops suddenly, the motion continuing in the man, he is thrown forward. If a man were

to jump from the land into a swift-sailing ship, he would be thrown backward, or towards the stern, not having at first the motion of the ship.

He that travels by sea or land towards the equinoctial, gradually acquires motion; from it, loses.

But if a man were taken up from lat. 40. (where suppose the earth's surface to move twelve miles per minute,) and immediately set down at the equinoctial, without changing the motion he had, his heels would be struck up, he would fall westward. If taken up from the equinoctial, and set down in lat. 40. he would fall eastward.

The air under the equator and between the tropics being constantly heated and rarefied by the sun, rises. Its place is supplied by air from northern and southern latitudes, which coming from parts where the earth and air had less motion, and not suddenly acquiring the quicker motion of the equatorial earth, appears an east wind blowing westward, the earth moving from west to east, and slipping under the air.

Thus when we ride in a calm, it seems a wind against us. If we ride with the wind and faster, even that will seem a small wind against us.

The air rarefied between the tropics, and rising, must flow in the north and south higher region: before it rose it had acquired the greatest motion the earth's rotation could give it. It retains some degree of this motion, and descending in higher latitudes where the earth's motion is less, will ap-

pear a westerly wind, yet tending towards the equinoctial parts to supply the vacancy occasioned by the air of the lower regions flowing thitherwards.

Hence our general cold winds are about the north-west, our summer cold gusts the same.

The air in sultry weather, though not cloudy, has a kind of haziness in it, which makes objects at distances appear dull and indistinct. This haziness is occasioned by the great quantity of moisture equally diffused in that air. When by the cold wind blowing down among it, it is condensed into clouds and falls in rain, the air becomes purer and clearer: hence after gusts, distant objects appear distinct, their figures sharply terminated.

Extreme cold winds congeal the surface of the earth, by carrying off its fire. Warm winds afterwards blowing over that frozen surface, will be chilled by it. Could that frozen surface be turned under, and a warmer turned up from beneath it, these warm winds would not be chilled so much. The surface of the earth is also sometimes much heated by the sun; and such heated surface not being changed, heats the air that moves over it.

Seas, lakes, and great bodies of water agitated by the winds, continually change surfaces; the cold surface in winter is turned under by the rolling of the waves (*and the air over it,*) and a warmer turned up: in summer the warm turned under,

and cooler turned up. Hence the more equal temper of sea-water, and the air over it. Hence in winter, winds from the sea seem warm, winds from the land cold. In summer the contrary.

Therefore the lakes north-west of us,[1] as they are not so much frozen nor so apt to freeze as the earth, rather moderate than increase the coldness of our winter winds.

The air over the sea being warmer, and therefore lighter in winter than the air over the frozen land, may be another cause of our general north-west winds; which blow off to sea at right angles from our North-American coast. The warm light sea air rising, the heavy cold land air pressing into its place.

Heavy fluids descending, frequently form eddies or whirlpools, as is seen in a funnel, where the water acquires a circular motion, receding every way from a centre, and leaving a vacancy in the middle, greatest above, and lessening downwards, like a speaking trumpet, its biggest end upwards.

Air ascending or descending may form the same kind of eddies or whirlings, the parts of air acquiring a circular motion, and receding from the middle of the circle by a centrifugal force, and leaving there a vacancy, if descending, greatest above, and lessening downwards; if ascending, greatest below and lessening upwards, like a

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[1] In Pennsylvania.

speaking trumpet standing its big end on the ground.

When the air descends with violence in some places, it may rise with equal violence in others, and form both kinds of whirlwinds.

The air in its whirling motion receding every way from the centre or axis of the trumpet, leaves there a vacuum, which cannot be filled through the sides, the whirling air as an arch preventing: it must then press in at the open ends.

The greatest pressure inwards must be at the lower end, the greatest weight of the surrounding atmosphere being there. The air entering rises within and carries up dust, leaves, and even heavier bodies that happen to be in its way, as the eddy or whirl passes over land.

If it passes over water, the weight of the surrounding atmosphere forces up the water into the vacuity, part of which by degrees joins with the whirling air, and adding weight and receiving accelerated motion, recedes still farther from the centre or axis of the trumpet as the pressure lessens, and at last is broken into small particles, and so united with air as to be supported by it, and become black clouds at the top of the trump.

Thus these eddies may be whirlwinds at land, water-spouts at sea. A body of water so raised may be suddenly let fall when the motion, &c. has not strength to support it, or the whirling arch is broken so as to let in the air. Falling in the sea,

it is harmless, unless ships happen to be under it. But if in the progressive motion of the whirl it has moved from the sea over to the land, and there breaks; sudden, violent, and mischievous torrents are the consequence. B. FRANKLIN.

ON ELECTRICITY.

A THREE WHEELED CLOCK—GRAVITATION OF BODIES AFFECTED BY SUN AND MOON—CONJECTURE ON TIDES.

TO DR. INGENHAUSZ.

MY DEAR FRIEND, *Passy, April* 29, 1785.

I believe my last letter to you was of May 16, 1783. I am therefore much in your debt as a correspondent. I have now before me all your letters since received, and shall endeavor as well as I can to answer them. I confess that a man who can leave so many letters so long unanswered, does not deserve so valuable a correspondence as yours. But I am grown very old, being now in my eightieth year: I am engaged in much business that must not be neglected. Writing becomes more and more irksome to me: I grow more indolent: philosophic discussions, not being urgent like business, are postponed from time to time till they are forgotten; besides, I have been these twenty months past afflicted with the stone, which is always giving me more or less uneasiness, unless when I am laid in bed; and when I would

write, it interrupts my train of thinking, so that I lay down my pen, and seek some light amusement.

I consent to your request concerning my paper on the weathercock struck by lightning.[1] Dispose of it as you please.

You will find an account of the first great stroke I received, in pages 160, 161, of my book, 5th edition, 1774.[2] The second I will now give you.

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[1] See WRITINGS, Part IV.

[2] Extract from the same.

Turkey killed by electricity—Effect of a shock on the operator in making the experiment.

As Mr. Franklin, in a former letter to Mr. Collinson, mentioned his intending to try the power of a very strong electrical shock upon a turkey, that gentleman accordingly has been so very obliging as to send an account of it, which is to the following purpose.

He made first several experiments on fowls, and found, that two large thin glass jars gilt, holding each about six gallons, were sufficient, when fully charged, to kill common hens outright; but the turkies, though thrown into violent convulsions, and then lying as dead for some minutes, would recover in less than a quarter of an hour. However, having added three other such to the former two, though not fully charged, he killed a turkey of about ten pounds' weight, and believes that they would have killed a much larger. He conceited, as himself says, that the birds killed in this manner ate uncommonly tender.

In making these experiments, he found, that a man could, without great detriment, bear a much greater shock than he had

I had a paralytic patient in my chamber, whose friends brought him to receive some electric shocks: I made them join hands so as to receive the shock at the same time, and I charged two large jars to give it. By the number of those people I was obliged to quit my usual standing, and placed myself inadvertently under an iron hook which hung from the ceiling down to within two inches of my head, and communicated by

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imagined: for he inadvertently received the stroke of two of these jars through his arms and body, when they were very near fully charged. It seemed to him an universal blow throughout the body from head to foot, and was followed by a violent quick trembling in the trunk, which went off gradually, in a few seconds. It was some minutes before he could recollect his thoughts, so as to know what was the matter; for he did not see the flash, though his eye was on the spot of the prime conductor, from whence it struck the back of his hand; nor did he hear the crack, though the by-standers said it was a loud one; nor did he particularly feel the stroke on his hand, though he afterwards found it had raised a swelling there, of the bigness of half a pistol-bullet. His arms and the back of the neck felt somewhat numbed the remainder of the evening, and his breast was sore for a week after, as if it had been bruised. From this experiment may be seen the danger, even under the greatest caution, to the operator, when making these experiments with large jars; for it is not to be doubted, that several of these fully charged would as certainly, by increasing them, in proportion to the size, kill a man, as they before did a turkey.

N. B. The original of this letter, which was read at the Royal Society, has been mislaid.

wire with the outside of the jars. I attempted to discharge them, and in fact did so; but I did not perceive it, though the charge went through me, and not through the persons I intended it for. I neither saw the flash, heard the report, nor felt the stroke. When my senses returned, I found myself on the floor. I got up, not knowing how that had happened. I then again attempted to discharge the jars; but one of the company told me they were already discharged, which I could not at first believe, but on trial found it true. They told me they had not felt it, but they saw I was knocked down by it, which had greatly surprised them. On recollecting myself, and examining my situation, I found the case clear. A small swelling rose on the top of my head, which continued sore for some days; but I do not remember any other effect, good or bad. The stroke you received, and its consequences, are much more curious. I communicated that part of your letter to an operator, encouraged by government here to electrify epileptic and other poor patients, and advised his trying the practice on mad people according to your opinion. I have not heard whether he has done it.

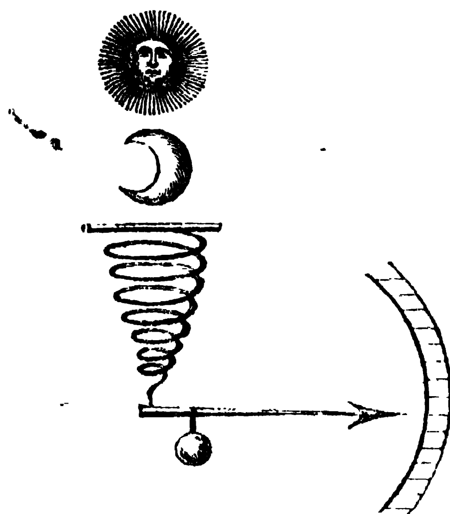
I do not know that my contrivance of a clock with three wheels only, which showed hours, minutes, and seconds, has ever been published. I have seen several of them here at Paris that were made by Mr. Whitehurst, and sent over I

believe by Mr. Magellan. You are welcome to do what you please with it. Mr. Whitehurst's invention is very simple, and should be very effectual, provided the foot of the rod and the situation of the clock are invariably fixed, so as never to be at a greater or less distance from one another, which may be by fixing both in a strait-grained piece of wood of about four feet long; wood not changing its dimensions the length-way of the grain, by any common degree of heat or cold. But this cannot be trusted to in the wood of a clock case, because in sawing boards the grain is frequently crossed, and moisture and dryness will change their dimensions.

You are at liberty also to publish, if you think fit, the experiment of the globe floating between two liquors. I suppose you remember to have seen it on my chimney-piece. Though it is a matter of no utility. Something of the same nature has been done more than an hundred years since by another person, I forget who.

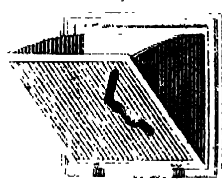
What I formerly mentioned to you of hanging a weight on a spiral spring, to discover if bodies gravitated differently to the earth during the conjunctions of the sun and moon, compared with other times, was this. We suppose that by the force of gravity in those luminaries, the water of the ocean, an immense weight, is elevated so as to form the tides: if that be so, might we not expect that an iron ball of a pound weight, suspended by

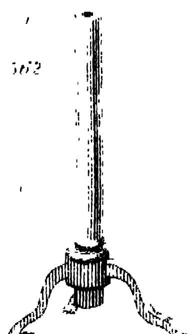
a fine spiral spring, should, when the sun and moon are together both above it, be a little at-

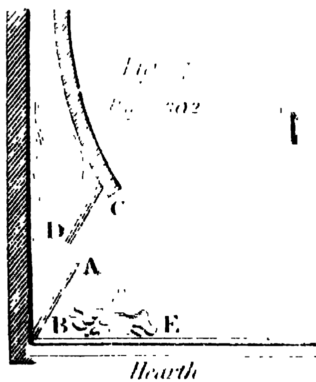


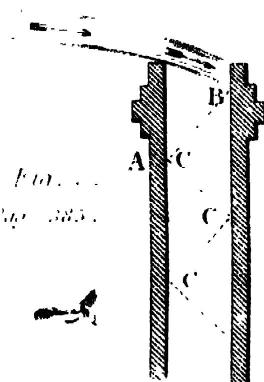
tracted upwards or rendered lighter, so as to be drawn up a little by the spring on which it depends, and the contrary when they are both below it. The quantity, though very small, might perhaps be rendered visible by a contrivance like the above. It is not difficult to make this experiment, but I have never made it. With regard to the tides, I doubt the opinion of there being but two high waters and two low waters existing at the same time on the globe. I rather think there are many, and those at the distance of about one hundred leagues from each other. The tides found in the river Amazons seem to favor this opinion. Observations hereafter in the isles of the Pacific Ocean, may confirm or refute it.

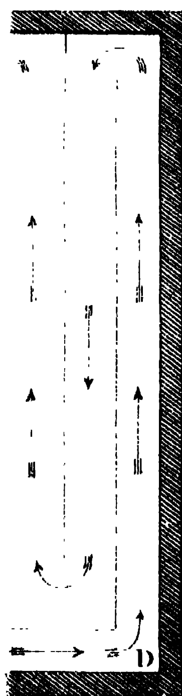
If I were in a situation where I could be a little more master of my time, I would, as you desire, write my ideas on the subject of chimnies; they

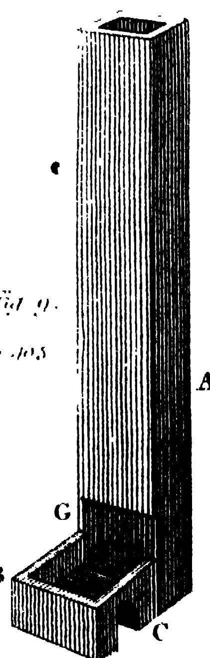





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Fig. 9.
Page 405
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might, I think, be useful. For by what I see everywhere the subject seems too little understood, which occasions much inconvenience and fruitless expense. But besides being harassed by too much business, I am exposed to numberless visits, some of kindness and civility, many of mere idle curiosity, from strangers of America and of different parts of Europe, as well as the inhabitants of the provinces who come to Paris. These devour my hours, and break my attention, and at night I often find myself fatigued without having done any thing. Celebrity may for a while flatter one's vanity, but its effects are troublesome. I have begun to write two or three things, which I wish to finish before I die; but I sometimes doubt the possibility.

* * * * *

B. Franklin.

ON THE CAUSES AND CURE OF SMOKY CHIMNIES.

To Dr. Ingenhausz.

Dear Friend, *At sea, Aug.* 28, 1785.

In one of your letters, a little before I left France, you desired me to give you in writing my thoughts upon the construction and use of chimnies, a subject you had sometimes heard me touch upon in conversation. I embrace willingly this leisure afforded by my present situation to comply

with your request, as it will not only show my regard to the desires of a friend, but may at the same time be of some utility to others; the doctrine of chimnies appearing not to be as yet generally well understood, and mistakes respecting them being attended with constant inconvenience, if not remedied, and with fruitless expense, if the true remedies are mistaken.

Those who would be acquainted with this subject, should begin by considering on what principle smoke ascends in any chimney. At first, many are apt to think that smoke is in its nature and of itself specifically lighter than air, and rises in it for the same reason that cork rises in water. These see no cause why smoke should not rise in the chimney, though the room be ever so close. Others think there is a power in chimnies to *draw up* the smoke, and that there are different forms of chimnies which afford more or less of this power. These amuse themselves with searching for the best form. The equal dimensions of a funnel in its whole length is not thought artificial enough, and it is made, for fancied reasons, sometimes tapering and narrowing from below upwards, and sometimes the contrary, &c. A simple experiment or two may serve to give more correct ideas. Having lit a pipe of tobacco, plunge the stem to the bottom of a decanter half filled with cold water; then putting a rag over the bowl, blow through it and make the smoke descend in the stem of the pipe.

from the end of which it will rise in bubbles through the water; and being thus cooled, will not afterwards rise to go out through the neck of the decanter, but remain spreading itself and resting on the surface of the water. This shows that smoke is really heavier than air, and that it is carried upwards only when attached to, or acted upon, by air that is heated, and thereby rarefied and rendered specifically lighter than the air in its neighborhood.

Smoke being rarely seen but in company with heated air, and its upward motion being visible, though that of the rarefied air that drives it is not so, has naturally given rise to the error.

I need not explain to you, my learned friend, what is meant by rarefied air; but if you make the public use you propose of this letter, it may fall into the hands of some who are unacquainted with the term and with the thing. These then may be told, that air is a fluid which has weight as well as others, though about eight hundred times lighter than water. That heat makes the particles of air recede from each other and take up more space, so that the same weight of air heated will have more bulk, than equal weights of cold air which may surround it, and in that case must rise, being forced upwards by such colder and heavier air, which presses to get under it and take its place. That air is so rarefied or expanded by heat, may be proved to their comprehension, by a lank blown bladder, which,

laid before a fire, will soon swell, grow tight, and burst.

Another experiment may be to take a glass tube about an inch in diameter, and twelve inches long, open at both ends, and fixed upright on legs, so that it need not be handled, for the hands might warm it. At the end of a quill fasten five or six inches of the finest light filament of silk, so that it may be held either above the upper end of the tube or under the lower end, your warm hand being at a distance by the length of the quill. (See the plate, fig. 1.) If there were any motion of air through the tube, it would manifest itself by its effect on the silk; but if the tube and the air in it are of the same temperature with the surrounding air, there will be no such motion, whatever may be the form of the tube, whether crooked or strait, narrow below and widening upwards, or the contrary; the air in it will be quiescent. Warm the tube, and you will find, as long as it continues warm, a constant current of air entering below and passing up through it, till discharged at the top; because the warmth of the tube being communicated to the air it contains, rarefies that air and makes it lighter than the air without, which therefore presses in below, forces it upwards, and follows and takes its place, and is rarefied in its turn. And, without warming the tube, if you hold under it a knob of hot iron, the air thereby heated will rise and fill the tube, going

out at its top; and this motion in the tube will continue as long as the knob remains hot, because the air entering the tube below is heated and rarefied by passing near and over that knob.

That this motion is produced merely by the difference of specific gravity between the fluid within and that without the tube, and not by any fancied form of the tube itself, may appear by plunging it into water contained in a glass jar a foot deep, through which such motion might be seen. The water within and without the tube being of the same specific gravity, balance each other, and both remain at rest. But take out the tube, stop its bottom with a finger, and fill it with olive oil, which is lighter than water, then stopping the top, place it as before, its lower end under water, its top a very little above: as long as you keep the bottom stopt the fluids remain at rest, but the moment it is unstopt, the heavier enters below, forces up the lighter, and takes its place. And the motion then ceases, merely because the new fluid cannot be successively made lighter, as air may be by a warm tube.

In fact, no form of the funnel of a chimney has any share in its operation or effect respecting smoke, except its height. The longer the funnel, if erect, the greater its force when filled with heated and rarefied air, to *draw* in below and drive up the smoke, if one may, in compliance with custom, use the expression *draw*, when in fact it is the superior

weight of the surrounding atmosphere that *presses* to enter the funnel below, and so *drives up* before it the smoke and warm air it meets with in its passage.

I have been the more particular in explaining these first principles, because, for want of clear ideas respecting them, much fruitless expense has been occasioned; not only single chimnies, but in some instances within my knowledge, whole stacks having been pulled down, and rebuilt with funnels of different forms, imagined more powerful in *drawing* smoke; but having still the same height and the same opening below, have performed no better than their predecessors.

What is it then which makes a *smoky chimney*, that is, a chimney which, instead of conveying up all the smoke, discharges a part of it into the room, offending the eyes and damaging the furniture?

The causes of this effect, which have fallen under my observation, amount to *nine*, differing from each other, and therefore requiring different remedies.

1. *Smoky chimnies in a new house, are such frequently from mere want of air.* The workmanship of the rooms being all good, and just out of the workman's hand, the joints of the boards of the flooring, and of the pannels of wainscotting are all true and tight, the more so as the walls, perhaps not yet thoroughly dry, preserve a dampness in the air of the room which keeps the wood-work

swelled and close. The doors and the sashes, too, being worked with truth, shut with exactness, so that the room is as tight as a snuff-box, no passage being left open for air to enter, except the key-hole, and even that is sometimes covered by a little dropping shutter. Now if smoke cannot rise but as connected with rarefied air, and a column of such air, suppose it filling the funnel, cannot rise, unless other air be admitted to supply its place; and if, therefore, no current of air enter the opening of the chimney, there is nothing to prevent the smoke coming out into the room. If the motion upwards of the air in a chimney that is freely supplied be observed by the rising of the smoke or a feather in it, and it be considered that in the time such feather takes in rising from the fire to the top of the chimney a column of air equal to the content of the funnel must be discharged, and an equal quantity supplied from the room below, it will appear absolutely impossible that this operation should go on if the tight room is kept shut; for were there any force capable of drawing constantly so much air out of it, it must soon be exhausted like the receiver of an air-pump, and no animal could live in it. Those therefore who stop every crevice in a room to prevent the admission of fresh air, and yet would have their chimney carry up the smoke, require inconsistencies, and expect impossibilities. Yet under this situation, I have seen the owner of a new house, in despair, and

ready to sell it for much less than it cost, conceiving it uninhabitable, because not a chimney in any one of its rooms would carry off the smoke, unless a door or window were left open. Much expense has also frequently been gone into to alter and amend new chimnies which had really no fault; in one house particularly that I knew, of a nobleman in Westminster, that expense amounted to no less than three hundred pounds, *after* his house had been, as he thought, finished and all charges paid. And after all, several of the alterations were ineffectual, for want of understanding the true principles.

Remedies. When you find on trial, that opening the door or a window enables the chimney to carry up all the smoke, you may be sure that want of air *from without* was the cause of its smoking. I say *from without*, to guard you against a common mistake of those who may tell you the room is large, contains abundance of air, sufficient to supply any chimney, and therefore it cannot be that the chimney wants air. These reasoners are ignorant that the largeness of a room, if tight, is in this case of small importance, since it cannot part with a chimney-ful of air without occasioning so much vacuum; which it requires a great force to effect, and could not be borne if effected.

It appearing plainly, then, that some of the outward air must be admitted, the question will be, how much is *absolutely necessary?* for you would

avoid admitting more, as being contrary to one of your intentions in having a fire, viz. that of warming your room. To discover this quantity, shut the door gradually while a middling fire is burning, till you find that, before it is quite shut, the smoke begins to come out into the room, then open it a little till you perceive the smoke comes out no longer. There hold the door, and observe the width of the open crevice between the edge of the door and the rabbit it should shut into. Suppose the distance to be half an inch, and the door eight feet high, you find thence that your room requires an entrance for air equal in area to ninety-six half inches, or forty-eight square inches, or a passage of six inches by eight. This however is a large supposition, there being few chimnies that, having a moderate opening and a tolerable height of funnel, will not be satisfied with such a crevice of a quarter of an inch; and I have found a square of six by six, or thirty-six square inches, to be a pretty good medium, that will serve for most chimnies. High funnels, with small and low openings, may indeed be supplied through a less space, because for reasons that will appear hereafter, the *force of levity*, if one may so speak, being greater in such funnels, the cool air enters the room with greater velocity, and consequently more enters in the same time. This however has its limits; for experience shows, that no increased velocity, so occasioned, has made the admission of air through the key-

hole equal in quantity to that through an open door; though through the door the current moves slowly, and through the key-hole with great rapidity.

It remains then to be considered how and where this necessary quantity of air from without is to be admitted so as to be least inconvenient. For if at the door, left so much open, the air thence proceeds directly to the chimney, and in its way comes cold to your back and heels as you sit before your fire. If you keep the door shut, and raise a little the sash of your window, you feel the same inconvenience. Various have been the contrivances to avoid this, such as bringing in fresh air through pipes in the jambs of the chimney, which, pointing upwards, should blow the smoke up the funnel; opening passages into the funnel above, to let in air for the same purpose. But these produce an effect contrary to that intended; for as it is the constant current of air passing from the room *through the opening of the chimney* into the funnel which prevents the smoke coming out into the room, if you supply the funnel by other means or in other ways with the air it wants, and especially if that air be cold, you diminish the force of that current, and the smoke in its effort to enter the room finds less resistance.

The wanted air must then *indispensably* be admitted into the room, to supply what goes off through the opening of the chimney. M. Gauger,

a very ingenious and intelligent French writer on the subject, proposes with judgment to admit it *above* the opening of the chimney; and to prevent inconvenience from its coldness, he directs its being made to pass in its entrance through winding cavities made behind the iron back and sides of the fire-place, and under the iron hearth-plate; in which cavities it will be warmed, and even heated, so as to contribute much, instead of cooling, to the warming of the room. This invention is excellent in itself, and may be used with advantage in building new houses; because the chimnies may then be so disposed as to admit conveniently the cold air to enter such passages: but in houses built without such views, the chimnies are often so situated, as not to afford that convenience, without great and expensive alterations. Easy and cheap methods, though not quite so perfect in themselves, are of more general utility; and such are the following.

In all rooms where there is a fire, the body of air warmed and rarefied before the chimney is continually changing place, and making room for other air that is to be warmed in its turn. Part of it enters and goes up the chimney, and the rest rises and takes place near the ceiling. If the room be lofty, that warm air remains above our heads as long as it continues warm, and we are little benefited by it, because it does not descend till it is cooler. Few can imagine the difference of climate

between the upper and lower parts of such a room, who have not tried it by the thermometer, or by going up a ladder till their heads are near the ceiling. It is then among this warm air that the wanted quantity of outward air is best admitted, with which being mixed, its coldness is abated, and its inconvenience diminished so as to become scarce observable. This may be easily done by drawing down about an inch the upper sash of a window; or, if not moveable, by cutting such a crevice through its frame; in both which cases, it will be well to place a thin shelf of the length, to conceal the opening, and sloping upwards to direct the entering air horizontally along and under the ceiling. In some houses the air may be admitted by such a crevice made in the wainscoat, cornice, or plastering, near the ceiling and over the opening of the chimney. This, if practicable, is to be chosen, because the entering cold air will there meet with the warmest rising air from before the fire, and be soonest tempered by the mixture. The same kind of shelf should also be placed here. Another way, and not a very difficult one, is to take out an upper pane of glass in one of your sashes, fixing it in a tin frame, (plate IV. fig. 2.) giving it two springing angular sides, and then replacing it, with hinges below on which it may be turned to open more or less above. It will then have the appearance of an internal sky-light. By drawing this pane in, more or less, you may admit what air

you find necessary. Its position will naturally throw that air up and along the ceiling. This is what is called in France a *Was ist das?* As this is a German question, the invention is probably of that nation, and takes its name from the frequent asking of that question when it first appeared. In England, some have of late years cut a round hole about five inches diameter in a pane of the sash and placed against it a circular plate of tin hung on an axis, and cut into vanes, which, being separately bent a little obliquely, are acted upon by the entering air, so as to force the plate continually round like the vanes of a windmill. This admits the outward air, and by the continual whirling of the vanes, does in some degree disperse it. The noise only is a little inconvenient.

2. A second cause of the smoking of chimnies is, *their openings in the room being too large;* that is, too wide, too high, or both. Architects in general have no other ideas of proportion in the opening of a chimney, than what relate to symmetry and beauty, respecting the dimensions of the room:[1] while its true proportion, respecting its functions and utility, depends on quite other principles; and they might as properly proportion the step in a staircase to the height of the story, instead of the natural elevation of men's legs in mounting. The proportion then to be regarded, is what re-

[1] See Notes at the end of this paper, No. I.

lates to the height of the funnel. For as the funnels in the different stories of a house are necessarily of different heights or lengths, that from the lowest floor being the highest or longest, and those of the other floors shorter and shorter, till we come to those in the garrets, which are of course the shortest; and the force of draft being, as already said, in proportion to the height of funnel filled with rarefied air; and a current of air from the room into the chimney, sufficient to fill the opening, being necessary to oppose and prevent the smoke coming out into the room; it follows, that the openings of the longest funnels may be larger, and that those of the shorter funnels should be smaller. For if there be a large opening to a chimney that does not draw strongly, the funnel may happen to be furnished with the air it demands by a partial current entering on one side of the opening, and, leaving the other side free of any opposing current, may permit the smoke to issue there into the room. Much too of the force of draught in a funnel depends on the degree of rarefaction in the air it contains, and that depends on the nearness to the fire of its passage in entering the funnel. If it can enter far from the fire on each side, or far above the fire, in a wide or high opening, it receives little heat in passing by the fire, and the contents of the funnel is by that means less different in levity from the surrounding atmosphere, and its force in drawing consequently weaker. Hence if too large an

opening be given to chimnies in upper rooms, those rooms will be smoky: on the other hand, if too small openings be given to chimnies in the lower rooms, the entering air, operating too directly and violently on the fire, and afterwards strengthening the draft as it ascends the funnel, will consume the fuel too rapidly.

Remedy. As different circumstances frequently mix themselves in these matters, it is difficult to give precise dimensions for the openings of all chimnies. Our fathers made them generally much too large; we have lessened them; but they are often still of greater dimension than they should be, the human eye not being easily reconciled to sudden and great changes. If you suspect that your chimney smokes from the too great dimension of its opening, contract it by placing moveable boards so as to lower and narrow it gradually, till you find the smoke no longer issues into the room. The proportion so found will be that which is proper for that chimney, and you may employ the bricklayer or mason to reduce it accordingly. However, as in building new houses, something must be sometimes hazarded, I would make the openings in my lower rooms about thirty inches square and eighteen deep, and those in the upper only eighteen inches square and not quite so deep; the intermediate ones diminishing in proportion as the height of funnel diminished. In the larger

openings, billets of two feet long, or half the common length of cord-wood, may be burnt conveniently; and for the smaller, such wood may be sawed into thirds. Where coals are the fuel, the grates will be proportioned to the openings. The same depth is nearly necessary to all, the funnels being all made of a size proper to admit of a chimney-sweeper. If in large and elegant rooms custom or fancy should require the appearance of a large chimney, it may be formed of extensive marginal decorations, in marble, &c. In time, perhaps, that which is fittest in the nature of things may come to be thought handsomest. But at present, when men and women in different countries show themselves dissatisfied with the forms God has given to their heads, waists and feet, and pretend to shape them more perfectly, it is hardly to be expected that they will be content always with the best form of a chimney. And there are some, I know, so bigotted to the fancy of a large noble opening, that rather than change it, they would submit to have damaged furniture, sore eyes, and skins almost smoked to bacon.

3. Another cause of smoky chimnies is, *too short a funnel.* This happens necessarily in some cases, as where a chimney is required in a low building; for if the funnel be raised high above the roof, in order to strengthen its draught, it is in danger of being blown down, and crushing the roof in its fall.

Remedies. Contract the opening of the chimney so as to oblige all the entering air to pass through or very near the fire, whereby it will be more heated and rarefied, the funnel itself be more warmed, and its contents have more of what may be called the force of levity, so as to rise strongly and maintain a good draught at the opening.

Or you may in some cases, to advantage, build additional stories over the low building, which will support a high funnel.

If the low building be used as a kitchen, and a contraction of the opening therefore inconvenient, a large one being necessary, at least when there are great dinners, for the free management of so many cooking utensils; in such case I would advise the building of two more funnels joining to the first, and having three moderate openings, one to each funnel, instead of one large one. When there is occasion to use but one, the other two may be kept shut by sliding plates, hereafter to be described;[1] and two or all of them may be used together when wanted. This will indeed be an expense, but not an useless one, since your cooks will work with more comfort, see better than in a smoky kitchen what they are about, your victuals will be cleaner dressed, and not taste of smoke, as is often the case; and to render the effect more certain, a stack

[1] See Notes at the end of this Paper, No. II.

of three funnels may be safely built higher above the roof than a single funnel.

The case of too short a funnel is more general than would be imagined, and often found where one would not expect it. For it is not uncommon, in ill-contrived buildings, instead of having a funnel for each room or fire-place, to bend and turn the funnel of an upper room so as to make it enter the side of another funnel that comes from below. By this means the upper room funnel is made short of course, since its length can only be reckoned from the place where it enters the lower room funnel; and that funnel is also shortened by all the distance between the entrance of the second funnel and the top of the stack; for all that part being readily supplied with air through the second funnel, adds no strength to the draught, especially as the air is cold where there is no fire in the second chimney. The only easy remedy here is, to keep the opening shut of that funnel in which there is no fire.

4. Another very common cause of the smoking of chimnies is, *their overpowering one another.* For instance, if there be two chimnies in one large room, and you make fires in both of them, the doors and windows close shut, you will find that the greater and stronger fire shall overpower the weaker, and draw air down its funnel to supply its own demand; which air descending in the weaker funnel will drive down its smoke, and force it into

the room. If, instead of being in one room, the two chimnies are in two different rooms, communicating by a door, the case is the same whenever that door is open. In a very tight house, I have known a kitchen chimney on the lowest floor, when it had a great fire in it, overpower any other chimney in the house, and draw air and smoke into its room, as often as the door was opened communicating with the staircase.

Remedy. Take care that every room has the means of supplying itself from without, with the air its chimney may require, so that no one of them may be obliged to borrow from another, nor under the necessity of lending. A variety of these means have been already described.

5. Another cause of smoking is, *when the tops of chimnies are commanded by higher buildings, or by a hill*, so that the wind blowing over such eminences falls like water over a dam, sometimes almost perpendicularly on the tops of the chimnies that lie in its way, and beats down the smoke contained in them.

Remedy. That commonly applied to this case, is a turncap made of tin or plate iron, covering the chimney above and on three sides, open on one side, turning on a spindle, and which, being guided or governed by a vane, always presents its back to the current. This I believe may be generally effectual, though not certain, as there may be cases in

which it will not succeed. Raising your funnels, if practicable, so as their tops may be higher, or at least equal with the commanding eminence, is more to be depended on. But the turning cap, being easier and cheaper, should first be tried. If obliged to build in such a situation, I would choose to place my doors on the side next the hill, and the backs of my chimnies on the further side; for then the column of air falling over the eminence, and of course pressing on that below, and forcing it to enter the doors, or *Was-ist-dases* on that side, would tend to balance the pressure down the chimnies, and leave the funnels more free in the exercise of their functions.

6. There is another case of command, the reverse of that last mentioned. It is where the commanding eminence is farther from the wind than the chimney commanded. To explain this a figure may be necessary. Suppose then a building (Plate IV. figure 3.) whose side A, happens to be exposed to the wind, and forms a kind of dam against its progress; the air obstructed by this dam will, like water, press and search for passages through it; and finding the top of the chimney B, below the top of the dam, it will force itself down that funnel, in order to get through by some door or window open on the side of the building. And if there be a fire in such chimney, its smoke is of course beat down, and fills the room.

Remedy. I know of but one, which is to raise such funnel higher than the roof, supporting it, if necessary, by iron bars. For a turn-cap in this case has no effect, the damm'd up air pressing down through it in whatever position the wind may have placed its opening.

I know a city in which many houses are rendered smoky by this operation. For their kitchens being built behind, and connected by a passage with the houses, and the tops of the kitchen chimnies lower than the top of the houses, the whole side of a street, when the wind blows against its back, forms such a dam as above described; and the wind, so obstructed, forces down those kitchen chimnies (especially when they have but weak fires in them) to pass through the passage and house into the street. Kitchen chimnies, so formed and situated, have another inconvenience. In summer, if you open your upper room windows for air, a light breeze blowing over your kitchen chimney towards the house, though not strong enough to force down its smoke as aforesaid, is sufficient to waft it into your windows, and fill the rooms with it; which, besides the disagreeableness, damages your furniture.

7. Chimnies, otherwise drawing well, are sometimes made to smoke by *the improper and inconvenient situation of a door.* When the door and chimney are on the same side of the room as in plate IV. figure 4, if the door A, being in the corner, is

made to open against the wall which is common, as being there, when open, more out of the way, it follows, that when the door is only opened in part, a current of air rushing in passes along the wall into and across the opening of the chimney B, and flirts some of the smoke out into the room. This happens more certainly when the door is shutting, for then the force of the current is augmented, and becomes very inconvenient to those who, warming themselves by the fire, happen to sit in its way.

The *remedies* are obvious and easy. Either put an intervening skreen from the wall round great part of the fire-place; or, which is perhaps preferable, shift the hinges of your door, so as it may open the other way, and when open throw the air along the other wall.

8. A room, that has no fire in its chimney, is sometimes filled with *smoke which is received at the top of its funnel and descends into the room.* In a former paper[1] I have already explained the descending currents of air in cold funnels; it may not be amiss however to repeat here, that funnels without fires have an effect, according to their degree of coldness or warmth, on the air that happens to be contained in them. The surrounding atmosphere is frequently changing its temperature; but stacks of funnels, covered from winds and sun by the house that contains them, retain a more

[1] See Notes at the end of this paper, No. II.

equal temperature. If, after a warm season, the outward air suddenly grows cold, the empty warm funnels begin to draw strongly upward; that is, they rarefy the air contained in them, which of course rises, cooler air enters below to supply its place, is rarefied in its turn, and rises; and this operation continues till the funnel grows cooler, or the outward air warmer, or both, when the motion ceases. On the other hand, if after a cold season, the outward air suddenly grows warm and of course lighter, the air contained in the cool funnels, being heavier, descends into the room; and the warmer air which enters their tops being cooled in its turn, and made heavier, continues to descend; and this operation goes on till the funnels are warmed by the passing of warm air through them, or the air itself grows cooler. When the temperature of the air and of the funnels is nearly equal, the difference of warmth in the air between day and night is sufficient to produce these currents, the air will begin to ascend the funnels as the cool of the evening comes on, and this current will continue till perhaps nine or ten o'clock the next morning, when it begins to hesitate; and as the heat of the day approaches, it sets downwards, and continues so till towards evening, when it again hesitates for some time, and then goes upwards constantly during the night, as before mentioned. Now when smoke issuing from the tops of neighboring funnels passes over the tops of fun-

nels which are at the time drawing downwards, as they often are in the middle part of the day, such smoke is of necessity drawn into these funnels, and descends with the air into the chamber.

The *remedy* is to have a sliding plate, hereafter described,[1] that will shut perfectly the offending funnel.

9. Chimnies which generally draw well, do nevertheless sometimes give smoke into the rooms, *it being driven down by strong winds passing over the tops of their funnels*, though not descending from any commanding eminence. This case is most frequent where the funnel is short, and the opening turned from the wind. It is more grievous, when it happens to be a cold wind that produces the effect, because when you most want your fire, you are sometimes obliged to extinguish it. To understand this, it may be considered that the rising light air, to obtain a free issue from the funnel, must push out of its way or oblige the air that is over it to rise. In a time of calm or of little wind this is done visibly, for we see the smoke that is brought up by that air rise in a column above the chimney. But when a violent current of air, that is, a strong wind, passes over the top of a chimney, its particles have received so much force, which keeps them in a horizontal direction, and follow each other so rapidly, that the rising light air has

[1] See Notes at the end of this paper, No. II.

not strength sufficient to oblige them to quit that direction and move upwards to permit its issue. Add to this, that some of the current passing over that side of the funnel which it first meets with, viz. at A. (plate IV. figure 5.) having been compressed by the resistance of the funnel, may expand itself over the flue, and strike the interior opposite side at B, from whence it may be reflected downwards and from side to side in the direction of the pricked lines c c c.

Remedies. In some places, particularly in Venice, where they have not stacks of chimnies but single flues, the custom is, to open or widen the top of the flue rounding in the true form of a funnel; (plate IV. figure 6.) which some think may prevent the effect just mentioned; for that the wind blowing over one of the edges into the funnel, may be slanted out again on the other side by its form. I have had no experience of this; but I have lived in a windy country, where the contrary is practised, the tops of the flues being *narrowed* inwards, so as to form a slit for the issue of the smoke, long as the breadth of the funnel, and only four inches wide. This seems to have been contrived on a supposition, that the entry of the wind would thereby be obstructed, and perhaps it might have been imagined, that the whole force of the rising warm air being condensed, as it were, in the narrow opening, would thereby be strengthened, so as to overcome the resistance of the wind. This however did not

always succeed; for when the wind was at north-east and blew fresh, the smoke was forced down by fits into the room I commonly sat in, so as to oblige me to shift the fire into another. The position of the slit of this funnel was indeed north-east and south-west. Perhaps if it had lain across the wind, the effect might have been different. But on this I can give no certainty. It seems a matter proper to be referred to experiment. Possibly a turn-cap might have been serviceable, but it was not tried.

Chimnies have not been long in use in England. I formerly saw a book printed in the time of queen Elizabeth, which remarked the then modern improvements of living, and mentioned among others the convenience of chimnies. "Our forefathers," said the author, "had no chimnies. There was in each dwelling-house only one place for a fire, and the smoke went out through a hole in the roof; but now there is scarce a gentleman's house in England that has not at least one chimney in it." When there was but one chimney, its top might then be opened as a funnel, and perhaps, borrowing the form from the Venetians, it was then the flue of a chimney got that name. Such is now the growth of luxury, that in both England and France we must have a chimney for every room, and in some houses every possessor of a chamber, and almost every servant, will have a fire; so that the flues being necessarily built in stacks,

the opening of each as a funnel is impracticable. This change of manners soon consumed the fire-wood of England, and will soon render fuel extremely scarce and dear in France, if the use of coals be not introduced in the latter kingdom as it has been in the former, where it at first met with opposition; for there is extant in the records of one of queen Elizabeth's parliaments, a motion made by a member, reciting, "That many dyers, brewers, smiths, and other artificers of London, had of late taken to the use of pitcoal for their fires, instead of wood, which filled the air with noxious vapors and smoke, very prejudicial to the health, particularly of persons coming out of the country; and therefore moving that a law might pass to prohibit the use of such fuel (at least during the session of parliament) by those artificers."—It seems it was not then commonly used in private houses. Its supposed unwholesomeness was an objection. Luckily the inhabitants of London have got over that objection, and now think it rather contributes to render their air salubrious, as they have had no general pestilential disorder since the general use of coals, when, before it, such were frequent. Paris still burns wood at an enormous expense, continually augmenting, the inhabitants having still that prejudice to overcome. In Germany you are happy in the use of stoves, which save fuel wonderfully: your people are very ingenious in the management of fire; but they may still learn something in that

art from the Chinese,[1] whose country being greatly populous and fully cultivated, has little room left for the growth of wood, and having not much other fuel that is good, have been forced upon many inventions during a course of ages, for making a little fire go as far as possible.

I have thus gone through all the common causes of the smoking of chimnies that I can at present recollect as having fallen under my observation; communicating the remedies that I have known successfully used for the different cases, together with the principles on which both the disease and the remedy depend, and confessing my ignorance wherever I have been sensible of it. You will do well, if you publish, as you propose, this letter, to add in notes, or as you please, such observations as may have occurred to your attentive mind; and if other philosophers will do the same, this part of science, though humble, yet of great utility, may in time be perfected. For many years past, I have rarely met with a case of a smoky chimney, which has not been solvable on these principles, and cured by these remedies, where people have been willing to apply them; which is indeed not always the case; for many have prejudices in favor of the nostrums of pretending chimney-doctors and fumists, and some have conceits and fancies of their own, which they rather choose to try, than

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[1] See Notes at the end of this paper, No. III.

to lengthen a funnel, alter the size of an opening, or admit air into a room, however necessary; for some are as much afraid of fresh air as persons in the hydrophobia are of fresh water. I myself had formerly this prejudice, this *aerophobia*, as I now account it, and dreading the supposed dangerous effects of cool air, I considered it as an enemy, and closed with extreme care every crevice in the rooms I inhabited. Experience has convinced me of my error. I now look upon fresh air as a friend: I even sleep with an open window. I am persuaded that no common air from without is so unwholesome as the air within a close room that has been often breathed and not changed. Moist air too, which formerly I thought pernicious, gives me now no apprehensions: for considering that no dampness of air applied to the outside of my skin can be equal to what is applied to and touches it within, my whole body being full of moisture, and finding that I can lie two hours in a bath twice a-week, covered with water, which certainly is much damper than any air can be, and this for years together, without catching cold, or being in any other manner disordered by it, I no longer dread mere moisture, either in air or in sheets or shirts: and I find it of importance to the happiness of life, the being freed from vain terrors, especially of objects that we are every day exposed inevitably to meet with. You physicians have of late happily discovered, after a contrary

opinion had prevailed some ages, that fresh and cool air does good to persons in the small pox and other fevers. It is to be hoped, that in another century or two we may all find out, that it is not bad even for people in health. And as to moist air, here I am at this present writing in a ship with above forty persons, who have had no other but moist air to breathe for six weeks past; every thing we touch is damp, and nothing dries, yet we are all as healthy as we should be on the mountains of Switzerland, whose inhabitants are not more so than those of Bermuda or St. Helena, islands on whose rocks the waves are dashed into millions of particles, which fill the air with damp, but produce no diseases, the moisture being pure, unmixed with the poisonous vapors arising from putrid marshes and stagnant pools, in which many insects die and corrupt the water. These places only, in my opinion, (which however I submit to yours) afford unwholesome air; and that it is not the mere water contained in damp air, but the volatile particles of corrupted animal matter mixed with that water, which renders such air pernicious to those who breathe it. And I imagine it a cause of the same kind that renders the air in close rooms, where the perspirable matter is breathed over and over again by a number of assembled people, so hurtful to health. After being in such a situation, many find themselves affected by that *febricula,* which the English call *a cold,* and, perhaps from the name,

imagine that they caught the malady by *going out* of the room, when it was in fact by being in it.

You begin to think that I wander from my subject, and go out of my depth. So I return again to my chimnies.

We have of late many lecturers in experimental philosophy. I have wished that some of them would study this branch of that science, and give experiments in it as a part of their lectures. The addition to their present apparatus need not be very expensive. A number of little representations of rooms, composed each of five panes of sash glass, framed in wood at the corners, with proportionable doors, and moveable glass chimnies, with openings of different sizes, and different lengths of funnel, and some of the rooms so contrived as to communicate on occasion with others, so as to form different combinations, and exemplify different cases; with quantities of green wax taper cut into pieces of an inch and half, sixteen of which stuck together in a square, and lit, would make a strong fire for a little glass chimney, and blown out, would continue to burn and give smoke as long as desired. With such an apparatus all the operations of smoke and rarefied air in rooms and chimnies might be seen through their transparent sides; and the effect of winds on chimnies, commanded or otherwise, might be shown by letting the entering air blow upon them through an opened window of the lecturer's chamber, where

it would be constant while he kept a good fire in his chimney. By the help of such lectures our fumists would become better instructed. At present they have generally but one remedy, which perhaps* they have known effectual in some one case of smoky chimnies, and they apply that indiscriminately to all the other causes, without success, —but not without expense to their employers.

With all the science, however, that a man shall suppose himself possessed of in this article, he may sometimes meet with cases that may puzzle him. I once lodged in a house at London, which, in a little room, had a single chimney and funnel. The opening was very small, yet it did not keep in the smoke, and all attempts to have a fire in this room were fruitless. I could not imagine the reason, till at length observing that the chamber over it, which had no fire-place in it, was always filled with smoke when a fire was kindled below, and that the smoke came through the cracks and crevices of the wainscot; I had the wainscot taken down, and discovered that the funnel which went up behind it, had a crack many feet in length, and wide enough to admit my arm, a breach very dangerous with regard to fire, and occasioned probably by an apparent irregular settling of one side of the house. The air entering this breach freely, destroyed the drawing force of the funnel. The remedy would have been, filling up the breach, or rather rebuilding the funnel; but the landlord rather chose to stop up the chimney.

Another puzzling case I met with at a friend's country-house near London. His best room had a chimney in which, he told me, he never could have a fire, for all the smoke came out into the room. I flattered myself I could easily find the cause, and prescribe the cure. I had a fire made there, and found it as he said. I opened the door and perceived it was not want of air. I made a temporary contraction of the opening of the chimney, and found that it was not its being too large that caused the smoke to issue. I went out and looked up at the top of the chimney: its funnel was joined in the same stack with others, some of them shorter, that drew very well, and I saw nothing to prevent its doing the same. In fine, after every other examination I could think of, I was obliged to own the insufficiency of my skill. But my friend, who made no pretensions to such kind of knowledge, afterwards discovered the cause himself. He got to the top of the funnel by a ladder, and looking down, found it filled with twigs and straw cemented by earth, and lined with feathers. It seems the house, after being built, had stood empty some years before he occupied it; and he concluded that some large birds had taken advantage of its retired situation to make their nest there. The rubbish, considerable in quantity, being removed, and the funnel cleared, the chimney drew well and gave satisfaction.

In general, smoke is a very tractable thing,

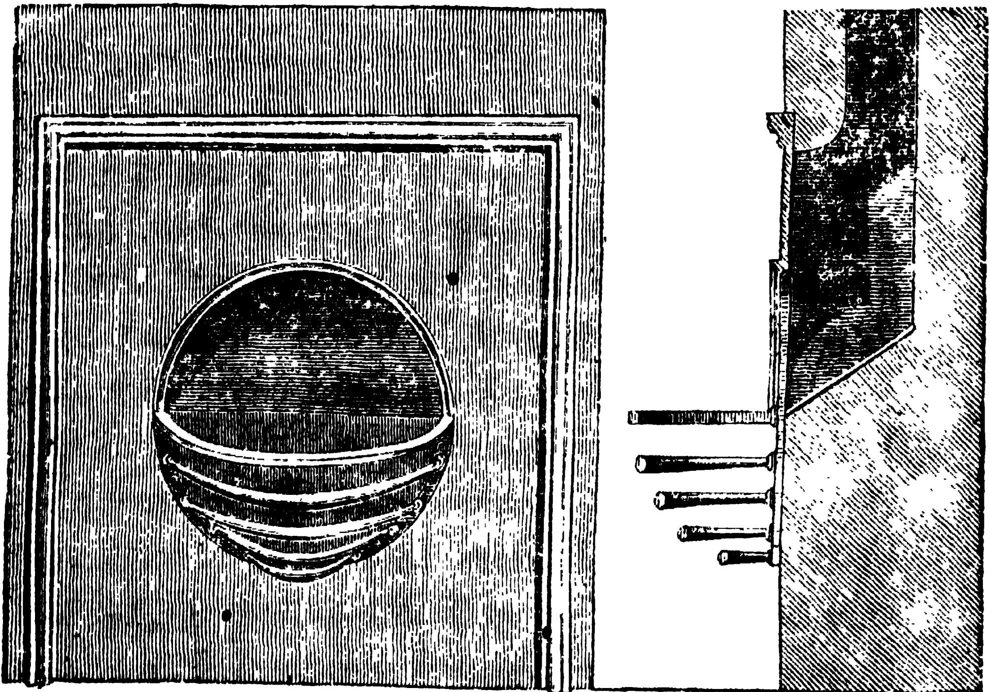
easily governed and directed when one knows the principles, and is well informed of the circumstances. You know I made it *descend* in my Pennsylvania stove. I formerly had a more simple construction, in which the same effect was produced, but visible to the eye. (Plate IV. figure 7.) It was composed of two plates, A B and C D, placed as in the figure. The lower plate A B rested with its edge in the angle made by the hearth with the back of the chimney. The upper plate was fixed to the breast, and lapped over the lower about six inches wide and the length of the plates (near two feet) between them. Every other passage of air into the funnel was well stopped. When therefore a fire was made at E, for the first time with charcoal, till the air in the funnel was a little heated through the plates, and then wood laid on, the smoke would rise to A, turn over the edge of that plate, descend to D, then turn under the edge of the upper plate, and go up the chimney. It was pretty to see, but of no great use. Placing therefore the under plate in a higher situation, I removed the upper plate C D, and placed it perpendicularly, (plate IV. figure 8,) so that the upper edge of the lower plate A B came within about three inches of it, and might be pushed farther from it, or suffered to come nearer to it, by a moveable wedge between them. The flame then ascending from the fire at E, was carried to strike the upper plate, made it very hot,

and its heat rose and spread with the rarefied air into the room.

I believe you have seen in use with me, the contrivance of a sliding plate over the fire, seemingly placed to oppose the rising of the smoke, leaving but a small passage for it, between the edge of the plate and the back of the chimney. It is particularly described, and its uses explained, in my former printed letter, and I mention it here only as another instance of the tractability of smoke.[1]

The Staffordshire fire-place, of which a representation is affixed, affords an example of the same kind.

Front View. *Side View.*



[1] See Notes at the end of this paper, No. II.

The opening of the chimney is bricked up, even with the fore edge of its jambs, leaving open only a passage over the grate of the same width, and perhaps eight inches high. The grate consists of semicircular bars, their upper bar of the greatest diameter, the others under it smaller and smaller, so that it has the appearance of half a round basket. It is, with the coals it contains, wholly without the wall that shuts up the chimney; yet the smoke bends and enters the passage above it, the draught being strong, because no air can enter that is not obliged to pass near or through the fire, so that all that the funnel is filled with is much heated, and of course much rarefied.

Much more of the prosperity of a winter country depends on the plenty and cheapness of fuel, than is generally imagined. In travelling I have observed, that in those parts where the inhabitants can have neither wood, nor coal, nor turf, but at excessive prices, the working people live in miserable hovels, are ragged, and have nothing comfortable about them. But when fuel is cheap (or where they have the art of managing it to advantage) they are well furnished with necessaries, and have decent habitations. The obvious reason is, that the working hours of such people are the profitable hours, and they who cannot afford sufficient fuel have fewer such hours in the twenty-four, than those who have it cheap and plenty: for much of the domestic work of poor women,

such as spinning, sewing, knitting, and of the men in those manufactures that require little bodily exercise, cannot well be performed where the fingers are numbed with cold; those people therefore, in cold weather, are induced to go to bed sooner, and lie longer in a morning than they would do if they could have good fires or warm stoves to sit by; and their hours of work are not sufficient to produce the means of comfortable subsistence. Those public works, therefore, such as roads, canals, &c. by which fuel may be brought cheap into such countries from distant places, are of great utility; and those who promote them may be reckoned among the benefactors of mankind.

I have great pleasure in having thus complied with your request, and in the reflection, that the friendship you honor me with, and in which I have ever been so happy, has continued so many years without the smallest interruption. Our distance from each other is now augmented, and nature must soon put an end to the possibility of my continuing our correspondence: but if consciousness and memory remain in a future state, my esteem and respect for you, my dear friend, will be everlasting. B. FRANKLIN.

Notes for the preceding Letter upon Chimnies.

No. I.

The latest work on architecture that I have seen, is that intitled *Nut-shells*, which appears to be

written by a very ingenious man, and contains a table of the proportions of the openings of chimnies; but they relate solely to the proportions he gives his rooms, without the smallest regard to the funnels. And he remarks, respecting those proportions, that they are similar to the harmonic divisions of a monochord.[1] He does not indeed lay much stress on this; but it shows that we like the appearance of principles; and where we have not true ones, we have some satisfaction in producing such as are imaginary.

No. II.

The description of the sliding plates here promised, and which hath been since brought into use under various names, with some immaterial changes, is contained in a former letter to James Bowdoin, Esq. as follows:

To James Bowdoin, Boston.

Dear Sir, *London, Dec.* 2, 1758.

I have executed here an easy simple contrivance, that I have long since had in speculation,

[1] "It may be just remarked here, that upon comparing these proportions with those arising from the common divisions of the monochord, it happens that the first answers to unisons; and although the second is a discord, the third answers to the third minor, the fourth to the third major, the fifth to the fourth, the sixth to the fifth, and the seventh to the octave." Nut shells, page 85.

for keeping rooms warmer in cold weather than they generally are, and with less fire. It is this: the opening of the chimney is contracted, by brick-work faced with marble slabs, to about two feet between the jambs, and the breast brought down to within about three feet of the hearth. An iron frame is placed just under the breast, and extending quite to the back of the chimney, so that a plate of the same metal may slide horizontally backwards and forwards in the grooves on each side of the frame. This plate is just so large as to fill the whole space, and shut the chimney entirely when thrust quite in, which is convenient when there is no fire. Drawing it out, so as to leave a space between its further edge and the back, of about two inches; this space is sufficient for the smoke to pass; and so large a part of the funnel being stopt by the rest of the plate, the passage of warm air out of the room, up the chimney, is obstructed and retarded, and by that means much cold air is prevented from coming in through crevices, to supply its place. This effect is made manifest three ways. First, when the fire burns briskly in cold weather, the howling or whistling noise made by the wind, as it enters the room through the crevices, when the chimney is open as usual, ceases as soon as the plate is slid in to its proper distance. Secondly, opening the door of the room about half an inch, and holding your hand against the opening, near the top of the door,

you feel the cold air coming in against your hand, but weakly, if the plate be in. Let another person suddenly draw it out, so as to let the air of the room go up the chimney with its usual freedom, where chimnies are open, and you immediately feel the cold air rushing in strongly. Thirdly, if something be set against the door, just sufficient, when the plate is in, to keep the door nearly shut, by resisting the pressure of the air that would force it open; then, when the plate is drawn out, the door will be forced open by the increased pressure of the outward cold air endeavoring to get in to supply the place of the warm air, that now passes out of the room to go up the chimney. In our common open chimnies, half the fuel is wasted, and its effect lost; the air it has warmed being immediately drawn off. Several of my acquaintance having seen this simple machine in my room, have imitated it at their own houses, and it seems likely to become pretty common. I describe it thus particularly to you, because I think it would be useful in Boston, where firing is often dear.

Mentioning chimnies put me in mind of a property I formerly had occasion to observe in them, which I have not found taken notice of by others; it is, that in the summer time, when no fire is made in the chimnies, there is, nevertheless, a regular draught of air through them, continually passing upwards, from about five or six o'clock in the afternoon, till eight or nine o'clock the next morning,

when the current begins to slacken and hesitate a little, for about half an hour, and then sets as strongly down again, which it continues to do till towards five in the afternoon, then slackens and hesitates as before, going sometimes a little up, then a little down, till, in about half an hour, it gets into a steady upward current for the night, which continues till eight or nine the next day; the hours varying a little as the days lengthen and shorten, and sometimes varying from sudden changes in the weather; as if, after being long warm, it should begin to grow cool about noon, while the air was coming down the chimney, the current will then change earlier than the usual hour, &c.

This property in chimnies I imagine we might turn to some account, and render improper, for the future, the old saying, *as useless as a chimney in summer*. If the opening of the chimney, from the breast down to the hearth, be closed by a slight moveable frame or two, in the manner of doors, covered with canvass, that will let the air through, but keep out the flies; and another little frame set within upon the hearth, with hooks on which to hang joints of meat, fowls, &c. wrapt well in wet linen cloths, three or four fold, I am confident, that if the linen is kept wet, by sprinkling it once a-day, the meat would be so cooled by the evaporation, carried on continually by means of the passing air, that it would keep a week or more

in the hottest weather. Butter and milk might likewise be kept cool, in vessels or bottles covered with wet cloths. A shallow tray, or keeler, should be under the frame to receive any water that might drip from the wetted cloths. I think, too, that this property of chimnies might, by means of smoke-jack vanes, be applied to some mechanical purposes, where a small but pretty constant power only is wanted.

If you would have my opinion of the cause of this changing current of air in chimnies, it is, in short, as follows. In summer time there is generally a great difference in the warmth of the air at mid-day and midnight, and, of course, a difference of specific gravity in the air, as the more it is warmed the more it is rarefied. The funnel of a chimney being for the most part surrounded by the house, is protected, in a great measure, from the direct action of the sun's rays, and also from the coldness of the night air. It thence preserves a middle temperature between the heat of the day and the coldness of the night. This middle temperature it communicates to the air contained in it. If the state of the outward air be cooler than that in the funnel of the chimney, it will, by being heavier, force it to rise, and go out at the top. What supplies its place from below being warmed, in its turn, by the warmer funnel, is likewise forced up by the colder and weightier air below, and so the current is continued till the next day, when the sun

gradually changes the state of the outward air, makes it first as warm as the funnel of the chimney can make it (when the current begins to hesitate) and afterwards warmer. The funnel, being cooler than the air that comes into it, cools that air, makes it heavier than the outward air, of course it descends; and what succeeds it from above being cooled in its turn, the descending current continues till towards evening, when it again hesitates and changes its course from the change of warmth in the outward air, and the nearly remaining same middle temperature in the funnel.

Upon this principle, if a house were built behind Beacon-hill, an adit carried from one of the doors into the hill horizontally, till it meet with a perpendicular shaft sunk from its top, it seems probable to me, that those who lived in the house would constantly, in the heat even of the calmest day, have as much cool air passing through the house as they should choose; and the same, though reversed in its current, during the stillest night.

I think, too, this property might be made of use to miners; as, where several shafts or pits are sunk perpendicularly into the earth, communicating at bottom by horizontal passages, which is a common case, if a chimney of thirty or forty feet high were built over one of the shafts, or so near the shaft that the chimney might communicate with the top of the shaft, all air being excluded but what should pass up or down by the shaft, a constant change of

air would by this means be produced in the passages below, tending to secure the workmen from those damps, which so frequently incommode them. For the fresh air would be almost always going down the open shaft, to go up the chimney, or down the chimney, to go up the shaft. Let me add one observation more, which is, that if that part of the funnel of a chimney which appears above the roof of a house be pretty long, and have three of its sides exposed to the heat of the sun successively, viz. when he is in the east, in the south, and in the west, while the north side is sheltered by the building from the cool northerly winds; such a chimney will often be so heated by the sun, as to continue the draught strongly upwards, through the whole twenty-four hours, and often for many days together. If the outside of such a chimney be painted black, the effect will be still greater, and the current stronger.

No. III.

It is said the northern Chinese have a method of warming their ground floors, which is ingenious. Those floors are made of tiles, a foot square and two inches thick, their corners being supported by bricks set on end, that are a foot long and four inches square; the tiles, too, join into each other, by ridges and hollows along their sides. This forms a hollow under the whole floor, which on one side of the house has an opening into the air

where a fire is made, and it has a funnel rising from the other side to carry off the smoke. The fuel is a sulphurous pitcoal, the smell of which in the room is thus avoided, while the floor, and of course the room, is well warmed. But as the underside of the floor must grow foul with soot, and a thick coat of soot prevents much of the direct application of the hot air to the tiles, I conceive that burning the smoke, by obliging it to descend through red coals, would in this construction be very advantageous, as more heat would be given by the flame than by the smoke, and the floor being thereby kept free from soot, would be more heated with less fire. For this purpose I would propose erecting the funnel close to the grate, so as to have only an iron plate between the fire and the funnel, through which plate, the air in the funnel being heated, it will be sure to draw well, and force the smoke to descend, as in the figure (Plate IV. Figure 9.) where A is the funnel or chimney, B the grate on which the fire is placed, C one of the apertures through which the descending smoke is drawn into the channel D of figure 10, along which channel it is conveyed by a circuitous route as designated by the arrows, until it arrives at the small aperture E, figure 10, through which it enters the funnel F. G in both figures is the iron plate against which the fire is made, which being heated thereby, will rarefy the air in that part of the funnel, and cause the smoke

to ascend rapidly. The flame thus dividing from the grate to the right and left, and turning in passages, disposed, as in figure 13, so as that every part of the floor may be visited by it before it enters the funnel F, by the two passages E E, very little of the heat will be lost, and a winter room thus rendered very comfortable.

No. IV.

Page 435. *Few can imagine, &c.* It is said the Icelanders have very little fuel, chiefly drift wood that comes upon their coast. To receive more advantage from its heat, they make their doors low, and have a stage round the room above the door, like a gallery, wherein the women can sit and work, the men read or write, &c. The roof being tight, the warm air is confined by it, and kept from rising higher and escaping; and the cold air, which enters the house when the door is opened, cannot rise above the level of the top of the door, because it is heavier than the warm air above the door, and so those in the gallery are not incommoded by it. Some of our too lofty rooms might have a stage so constructed as to make a temporary gallery above, for the winter, to be taken away in summer. Sedentary people would find much comfort there in cold weather.

No. V.

Page 451. *Where they have the art of managing it, &c.* In some houses of the lower people among the northern nations of Europe, and among the poorer sort of Germans in Pennsylvania, I have observed this construction, which appears very advantageous. (Plate IV. Figure 11.) A is the kitchen with its chimney; B an iron stove in the stove-room. In a corner of the chimney is a hole through the back into the stove, to put in fuel, and another hole above it to let the smoke of the stove come back into the chimney. As soon as the cooking is over, the brands in the kitchen chimney are put through the hole to supply the stove, so that there is seldom more than one fire burning at a time. In the floor over the stove-room is a small trap-door, to let the warm air rise occasionally into the chamber. Thus the whole house is warmed at little expense of wood, and the stove-room kept constantly warm; so that in the coldest winter nights, they can work late, and find the room still comfortable when they rise to work early. An English farmer in America, who makes great fires in large open chimnies, needs the constant employment of one man to cut and haul wood for supplying them; and the draught of cold air to them is so strong, that the heels of his family are frozen while they are scorching their faces, and the room is never warm, so that little sedentary

work can be done by them in winter. The difference in this article alone of economy shall, in a course of years, enable the German to buy out the Englishman, and take possession of his plantation.

Miscellaneous Observations.

Chimnies, whose funnels go up in the north wall of a house and are exposed to the north winds, are not so apt to draw well as those in a south wall; because, when rendered cold by those winds, they draw downwards.

Chimnies, enclosed in the body of a house, are better than those whose funnels are exposed in cold walls.

Chimnies in stacks are apt to draw better than separate funnels, because the funnels that have constant fires in them warm the others, in some degree, that have none.

One of the funnels, in a house I once occupied, had a particular funnel joined to the south side of the stack, so that three of its sides were exposed to the sun in the course of the day, viz. (Plate IV. Figure 12.) the east side E during the morning, the south side S in the middle part of the day, and the west side W during the afternoon, while its north side was sheltered by the stack from the cold winds. This funnel, which came from the ground-floor, and had a considerable height above

B. 2

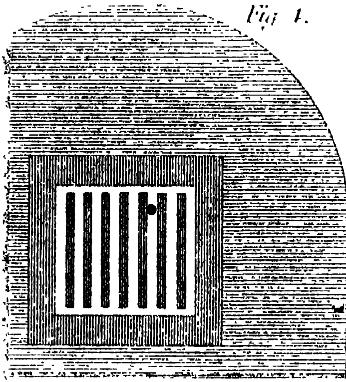


Fig. 4.

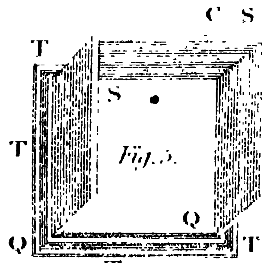


Fig. 5.

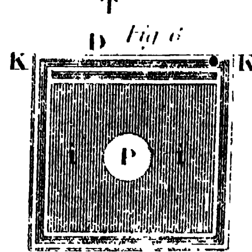


Fig. 6.

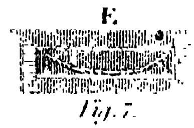
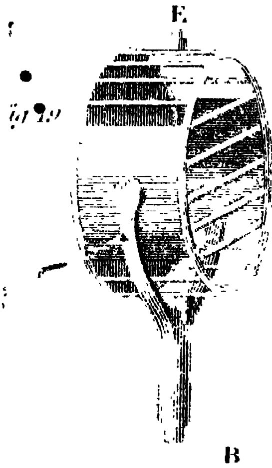
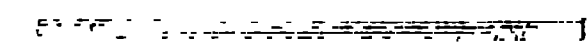


Fig. 7.



ig. 19

B





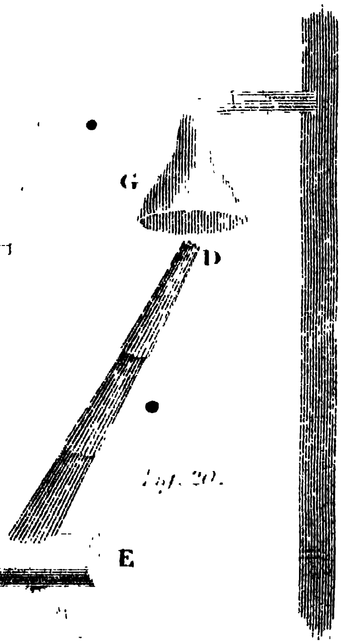


Fig. 20.

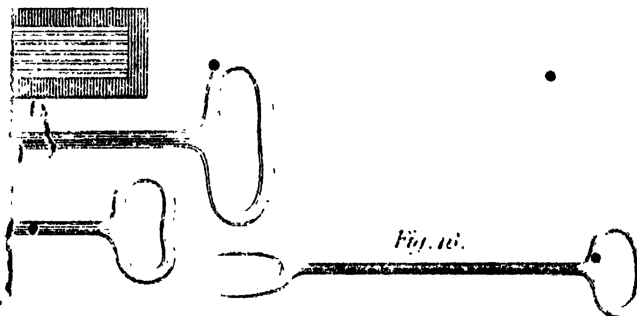


Fig. 18.

the roof, was constantly in a strong drawing state day and night, winter and summer.

Blacking of funnels, exposed to the sun, would probably make them draw still stronger.

In Paris I saw a fire-place so ingeniously contrived as to serve conveniently two rooms, a bed-chamber and a study. The funnel over the fire was round. The fire-place was of cast iron, (Plate IV. Figure 13.) having an upright back A, and two horizontal semicircular plates B C, the whole so ordered as to turn on the pivots D E. The plate B always stopped that part of the round funnel that was next to the room without fire, while the other half of the funnel over the fire was always open. By this means a servant in the morning could make a fire on the hearth C, then in the study, without disturbing the master by going into his chamber; and the master, when he rose, could with a touch of his foot turn the chimney on its pivots, and bring the fire into his chamber, keep it there as long as he wanted it, and turn it again when he went out, into his study. The room which had no fire in it was also warmed by the heat coming through the back plate, and spreading in the room, as it could not go up the chimney.

DESCRIPTION OF A NEW STOVE FOR BURNING PITCOAL, AND CONSUMING ALL ITS SMOKE.

WRITTEN AT SEA, 1785.

TOWARDS the end of the last century an ingenious French philosopher, whose name I am sorry I cannot recollect, exhibited an experiment to show, that very offensive things might be burnt in the middle of a chamber, such as woollen rags, feathers, &c. without creating the least smoke or smell. The machine in which it was made, if I remember right, was of this form, (see Plate VI. Figure 1.) made of plate iron. Some clear-burning charcoals were put into the opening of the short tube A, and supported there by the grate B. The air, as soon as the tubes grew warm, would ascend in the longer leg C, and go out at D; consequently air must enter at A, descending to B. In this course it must be heated by the burning coals through which it passed, and rise more forcibly in the longer tube, in proportion to its degree of heat or rarefaction, and length of that tube. For such a machine is a kind of inverted siphon; and as the greater weight of water in the longer leg of a common siphon in descending is accompanied by an ascent of the same fluid in the shorter; so, in this inverted siphon, the greater quantity of levity of air in the longer leg, in rising is accompanied by the descent of air in the shorter. The things to be burned being laid on the hot

coals at A, the smoke must descend through those coals, be converted into flame, which, after destroying the offensive smell, come out at the end of the longer tube as mere heated air.

Whoever would repeat this experiment with success, must take care that the part A B, of the short tube, be quite full of burning coals, so that no part of the smoke may descend and pass by them without going through them, and being converted into flame; and that the longer tube be so heated as that the current of ascending hot air is established in it before the things to be burnt are laid on the coals; otherwise there will be a disappointment.

It does not appear, either in the Memoirs of the Academy of Sciences, or Philosophical Transactions of the English Royal Society, that any improvement was ever made of this ingenious experiment, by applying it to useful purposes. But there is a German book, intitled *Vulcanus Famulans*, by John George Leutmann, P. D. printed at Wirtemberg in 1723, which describes, among a great variety of other stoves for warming rooms, one, which seems to have been formed on the same principle, and probably from the hint thereby given, though the French experiment is not mentioned. This book being scarce, I have translated the chapter describing the stove, viz.

"*Vulcanus Famulans.by John George Leutmann, P.D. Wirtemberg,* 1723.

"CHAP. VII.

"On a Stove, which draws downwards.

"Here follows the description of a sort of stove, which can easily be removed and again replaced at pleasure. This drives the fire down under itself, and gives no smoke, but however a very unwholesome vapor.

"In the figure, G is an iron vessel like a funnel, (Plate VI, Figure 20.) in diameter at the top about twelve inches, at the bottom near the grate about five inches; its height twelve inches. This is set on the barrel C, which is ten inches diameter and two feet long, closed at each end E E. From one end rises a pipe or flue about four inches diameter, on which other pieces of pipe are set, which are gradually contracted to D, where the opening is but about two inches. Those pipes must together be at least four feet high. B is an iron grate. F F are iron handles guarded with wood, by which the stove is to be lifted and moved. It stands on three legs. Care must be taken to stop well all the joints, that no smoke may leak through.

"When this stove is to be used, it must first be carried into the kitchen and placed in the chimney near the fire. There burning wood must be laid and left upon its grate till the barrel C is warm, and the smoke no longer rises at A, but descends

towards C. Then it is to be carried into the room which it is to warm. When once the barrel C is warm, fresh wood may be thrown into the vessel A as often as one pleases; the flame descends and without smoke, which is so consumed that only a vapor passes out at D.

"As this vapor is unwholesome, and affects the head, one may be freed from it, by fixing in the wall of the room an inverted funnel, such as people use to hang over lamps, through which their smoke goes out as through a chimney. This funnel carries out all the vapor cleverly, so that one finds no inconvenience from it, even though the opening D be placed a span below the mouth of the said funnel G. The neck of the funnel is better when made gradually bending, than if turned in a right angle.

"The cause of the draught downwards in the stove is the pressure of the outward air, which, falling into the vessel A in a column of twelve inches diameter, finds only a resisting passage at the grate B, of five inches, and one at D, of two inches, which are much too weak to drive it back again; besides, A stands much higher than B, and so the pressure on it is greater and more forcible, and beats down the frame to that part where it finds the least resistance. Carrying the machine first to the kitchen fire for preparation, is on this account, that in the beginning the fire and smoke naturally ascend, till the air in the close

barrel C is made thinner by the warmth. When that vessel is heated, the air in it is rarefied, and then all the smoke and fire descend under it.

"The wood should be thoroughly dry, and cut into pieces five or six inches long, to fit it for being thrown into the funnel A." Thus far the German book.

It appears to me, by Mr. Leutmann's explanation of the operation of this machine, that he did not understand the principles of it, whence I conclude he was not the inventor of it; and by the description of it, wherein the opening at A is made so large, and the pipe E D so short, I am persuaded he never made nor saw the experiment; for the first ought to be much smaller and the last much higher, or it hardly will succeed. The carrying it into the kitchen, too, every time the fire should happen to be out, must be so troublesome, that it is not likely ever to have been in practice, and probably has never been shown but as a philosophical experiment. The funnel for conveying the vapor out of the room would besides have been uncertain in its operation, as a wind blowing against its mouth would drive the vapor back.

The stove I am about to describe was also formed on the idea given by the French experiment, and completely carried into execution before I had any knowledge of the German invention; which I wonder should remain so many

years in a country, where the men are so ingenious in the management of fire, without receiving long ince the improvements I have given it.

Description of the Parts.

A, the bottom plate which lies flat upon the hearth, with its partitions, 1, 2, 3, 4, 5, 6, (Plate VI. Figure 2.) that are cast with it, and a groove Z Z, in which are to slide the bottom edges of the small plates Y Y, figure 12; which plates meeting at X, close the front.

B 1, figure 3, is the cover plate showing its under side, with the grooves 1, 2, 3, 4, 5, 6, to receive the top edges of the partitions that are fixed to the bottom plate. It shows also the grate W W, the bars of which are cast in the plate, and a groove V V, which comes right over the groove Z Z. figure 2, receiving the upper edges of the small sliding plates Y Y, figure 12.

B 2, figure 4, shows the upper side of the same plate, with a square impression or groove for receiving the bottom mouldings T, T, T, T, of the three-sided box C, figure 5, which is cast in one piece.

D, figure 6, its cover, showing its under side with grooves to receive the upper edges S S S of the sides of C, figure 5, also a groove R R, which when the cover is put on comes right over another Q Q in C, figure 5, between which it is to slide.

E, figure 7, the front plate of the box.

P, a hole three inches diameter through the cover

D, figure 6, over which hole stands the vase F, figure 8, which has a corresponding hole two inches diameter through its bottom.

The top of the vase opens at O, O, O, figure 8, and turns back upon a hinge behind when coals are to be put in; the vase has a grate within at NN of cast iron H, figure 9, and a hole in the top, one and a half inches diameter, to admit air, and to receive the ornamental brass gilt flame M, figure 10, which stands in that hole, and, being itself hollow and open, suffers air to pass through it into the fire.

G, figure 11, is a drawer of plate iron that slips in between in the partitions 2 and 3, figure 2, to receive the falling ashes. It is concealed when the small sliding plates Y Y, figure 12, are shut together.

I, I, I, I, figure 8, is a niche built of brick in the chimney and plastered. It closes the chimney over the vase, but leaves two funnels, one in each corner, communicating with the bottom box K K, figure 2.

Dimensions of the Parts.	FEET.	IN.
Front of the bottom box, - -	2	0
Height of its partitions, - - -	0	4¼
Length of No. 1, 2, 3, and 4, each, -	1	3
Length of No. 5 and 6, each, - -	0	8¼
Breadth of the passage between No. 2 and 3,	0	6
Breadth of the other passages each, -	0	3½
Breadth of the grate, - - -	0	6½
Length of ditto, - -	0	8

	FEET.	IN.
Bottom moulding of box C, square, -	1	0
Height of the sides of ditto, -	0	4
Length of the back side, - -	0	10
Length of the right and left sides, each,	0	9½
Length of the front plate E, where longest,	0	11
The cover D, square, - - -	0	12
Hole in ditto, diameter, - - -	0	3
Sliding plates Y Y, their length, each, -	1	0
................, their breadth, each,	0	4½
Drawer G, its length, - - -	0	1
.... breadth, - - -	0	5¾
.... depth, - - -	0	4
.... depth of its further end only,	0	1
Grate H in the vase, its diameter to the extremity of its knobs, - -	0	5
Thickness of the bars at top, - -	0	0¼
.... at bottom, less, -	0	0
Depth of the bars at the top, - -	0	0¾
Height of the vase, - - - - -	1	6
Diameter of the opening O, O, in the clear,	0	8
Diameter of the air-hole at top, - -	0	1½
.... of the flame-hole at bottom, -	0	2

To fix this machine.

Spread mortar on the hearth to bed the bottom plate A, then lay that plate level, equally distant from each jamb, and projecting out as far as you think proper. Then putting some Windsor loam in the grooves of the cover B, lay that on: trying the sliding plates Y Y, to see if they move freely in the grooves Z Z, V V, designed for them.

Then begin to build the niche, observing to

leave the square corners of the chimney unfilled; for they are to be funnels. And observe also to leave a free open communication between the passages at K K, and the bottom of those funnels, and mind to close the chimney above the top of the niche, that no air may pass up that way. The concave back of the niche will rest on the circular iron partition 1 A 4, figure 2: then with a little loam, put on the box C over the grate, the open side of the box in front.

Then, with loam in three of its grooves, the grooves R R being left clean, and brought directly over the groove Q Q in the box, put on the cover D, trying the front plate E, to see if it slides freely in those grooves.

Lastly, set on the vase, which has small holes in the moulding of its bottom to receive two iron pins that rise out of the plate D at I I, for the better keeping it steady.

Then putting in the grate H, which rests on its three knobs h h h against the inside of the vase, and slipping the drawer into its place; the machine is fit for use.

To use it.

Let the first fire be made after eight in the evening or before eight in the morning, for at those times and between those hours all night, there is usually a draught up a chimney, though it has long been without fire; but between those hours in the

day there is often, in a cold chimney, a draught downwards, when, if you attempt to kindle a fire, the smoke will come into the room.

But to be certain of your proper time, hold a flame over the air-hole at the top. If the flame is drawn strongly down for a continuance, without whiffling, you may begin to kindle a fire.

First put in a few charcoals on the grate H.

Lay some small sticks on the charcoals.

Lay some pieces of paper on the sticks.

Kindle the paper with a candle.

Then shut down the top, and the air will pass down through the air-hole; blow the flame of the paper down through the sticks, kindle them, and their flame passing lower kindles the charcoal.

When the charcoal is well kindled, lay on it the sea-coals, observing not to choak the fire by putting on too much at first.

The flame descending through the hole in the bottom of the vase, and that in plate D into the box C, passes down farther through the grate W W in plate B 1, then passes horizontally towards the back of the chimney; there dividing and turning to the right and left, one part of it passes round the far end of the partition 2, then coming forward it turns round the near end of partition 1, then moving backward it arrives at the opening into the bottom of one of the upright corner funnels behind the niche, through which it ascends into the chimney; thus heating that half of the box, and that

side of the niche. The other part of the divided flame passes round the far end of partition 3, round the near end of partition 4, and so into and up the other corner funnel, thus heating the other half of the box, and the other side of the niche. The vase itself, and the box C, will also be very hot, and the air surrounding them being heated, and rising, as it cannot get into the chimney, it spreads into the room, colder air succeeding is warmed in its turn, rises and spreads, till by the continual circulation the whole is warmed.

If you should have occasion to make your first fire at hours not so convenient as those above mentioned, and when the chimney does not draw, do not begin it in the vase, but in one or more of the passages of the lower plate, first covering the mouth of the vase. After the chimney has drawn a while with the fire thus low, and begins to be a little warm, you may close those passages and kindle another fire in the box C, leaving its sliding shutter a little open; and when you find after some time that the chimney being warmed draws forcibly, you may shut that passage, open your vase, and kindle your fire there, as above directed. The chimney, well warmed by the first day's fire, will continue to draw constantly all winter, if fires are made daily.

You will, in the management of your fire, have need of the following implements:

A pair of small light tongs, twelve or fifteen inches long, plate, figure 13.

A light poker about the same length, with a flat broad point, figure 14.

A rake to draw ashes out of the passages of the lower plate, where the lighter kind escaping the ash-box will gather by degrees, and perhaps once in a week or ten days require being removed, figure 15.

And a fork with its prongs wide enough to slip on the neck of the vase cover, in order to raise and open it when hot, to put in fresh coals, figure 16.

In the management of this stove there are certain precautions to be observed, at first with attention, till they become habitual. To avoid the inconvenience of smoke, see that the grate H be clear before you begin to light a fresh fire. If you find it clogged with cinders and ashes, turn it up with your tongs, and let them fall upon the grate below; the ashes will go through it, and the cinders may be raked off and returned into the vase when you would burn them. Then see that all the sliding plates are in their places and close shut, that no air may enter the stove but through the round opening at the top of the vase. And to avoid the inconvenience of dust from the ashes, let the ash-drawer be taken out of the room to be emptied: and when you rake the passages, do it when the draught of the air is strong inwards, and

put the ashes carefully into the ash-box, that remaining in its place.

If, being about to go abroad, you would prevent your fire burning in your absence, you may do it by taking the brass flame from the top of the vase, and covering the passage with a round tin plate, which will prevent the entry of more air than barely sufficient to keep a few of the coals alive. When you return, though some hours absent, by taking off the tin plate and admitting the air, your fire will soon be recovered.

The effect of this machine, well managed, is to burn not only the coals, but all the smoke of the coals, so that while the fire is burning, if you go out and observe the top of your chimney, you will see no smoke issuing, nor any thing but clear warm air, which, as usual, makes the bodies seen through it appear waving.

But let none imagine from this, that it may be a cure for bad or smoky chimnies, much less that, as it burns the smoke, it may be used in a room that has no chimney. It is by the help of a good chimney, the higher the better, that it produces its effect; and though a flue of plate iron sufficiently high might be raised in a very lofty room, the management to prevent all disagreeable vapor would be too nice for common practice, and small errors would have unpleasing consequences.

It is certain that clean iron yields no offensive smell when heated. Whatever of that kind you

perceive where there are iron stoves, proceeds therefore from some foulness burning or fuming on their surface. They should therefore never be spit upon, or greased, nor should any dust be suffered to lie upon them. But as the greatest care will not always prevent these things, it is well once a week to wash the stove with soap lees and a brush, rinsing it with clean water.

The Advantages of this Stove.

1. The chimney does not grow foul, nor ever need sweeping; for as no smoke enters it, no soot can form in it.

2. The air heated over common fires instantly quits the room and goes up the chimney with the smoke; but in the stove, it is obliged to descend in flame, and pass through the long winding horizontal passages, communicating its heat to a body of iron plate, which having thus time to receive the heat, communicates the same to the air of the room, and thereby warms it to a greater degree.

3. The whole of the fuel is consumed by being turned into flame, and you have the benefit of its heat; whereas in common chimnies a great part goes away in smoke, which you see as it rises, but it affords you no rays of warmth. One may obtain some notion of the quantity of fuel thus wasted in smoke, by reflecting on the quantity of soot that a few weeks' firing will lodge against the sides of the chimney, and yet this is formed only

of those particles of the column of smoke that happen to touch the sides in its ascent. How much more must have passed off in the air! And we know that this soot is still fuel: for it will burn and flame as such, and when hard caked together is indeed very like and almost as solid as the coal it proceeds from. The destruction of your fuel goes on nearly in the same quantity whether in smoke or in flame: but there is no comparison in the difference of heat given. Observe when fresh coals are first put on your fire, what a body of smoke arises. This smoke is for a long time too cold to take flame. If you then plunge a burning candle into it, the candle, instead of inflaming the smoke, will instantly be itself extinguished. Smoke must have a certain degree of heat to be inflammable. As soon as it has acquired that degree, the approach of a candle will inflame the whole body, and you will be very sensible of the difference of the heat it gives. A still easier experiment may be made with the candle itself. Hold your hand near the side of its flame, and observe the heat it gives; then blow it out, the hand remaining in the same place, and observe what heat may be given by the smoke that rises from the still burning snuff. You will find it very little. And yet that smoke has in it the substance of so much flame, and will instantly produce it, if you hold another candle above it so as to kindle it. Now the smoke from the fresh coals laid on this stove, instead of ascend-

ing and leaving the fire while too cold to burn, being obliged to descend through the burning coals, receives among them that degree of heat which converts it into flame, and the heat of that flame is communicated to the air of the room, as above explained.

4. The flame from the fresh coals laid on in this stove, descending through the coals already ignited, preserves them long from consuming, and continues them in the state of red coals as long as the flame continues that surrounds them, by which means the fires made in this stove are of much longer duration than in any other, and fewer coals are therefore necessary for a day. This is a very material advantage indeed. That flame should be a kind of *pickle*, to preserve burning coals from consuming, may seem a paradox to many, and very unlikely to be true, as it appeared to me the first time I observed the fact. I must therefore relate the circumstances, and shall mention an easy experiment, by which my reader may be in possession of every thing necessary to the understanding of it. In the first trial I made of this kind of stove, which was constructed of thin plate iron, I had, instead of the vase, a kind of inverted pyramid like a mill-hopper; and fearing at first that the small grate contained in it might be clogged by cinders, and the passage of the flame sometimes obstructed, I ordered a little door near the grate, by means of which I might on occasion

clear it: though after the stove was made, and before I tried it, I began to think this precaution superfluous, from an imagination, that the flame being contracted in the narrow part where the grate was placed, would be more powerful in consuming what it should there meet with, and that any cinders between or near the bars would be presently destroyed and the passage opened. After the stove was fixed and in action, I had a pleasure now and then in opening that door a little, to see through the crevice how the flame descended among the red coals; and observing once a single coal lodged on the bars in the middle of the focus, a fancy took me to observe with my watch in how short a time it would be consumed. I looked at it long without perceiving it to be at all diminished, which surprised me greatly. At length it occurred to me, that I and many others had seen the same things thousands of times, in the conservation of the red coal formed in the snuff of a burning candle, which while enveloped in flame, and thereby prevented from the contact of passing air, is long continued, and augments instead of diminishing, so that we are often obliged to remove it by the snuffers, or bend it out of the flame into the air, where it consumes presently to ashes. I then supposed, that to consume a body by fire, passing air was necessary to receive and carry off the separated particles of the body: and that the air passing in the flame of my stove, and

in the flame of a candle, being already saturated with such particles, could not receive more, and therefore left the coal undiminished as long as the outward air was prevented from coming to it by the surrounding flame, which kept it in a situation somewhat like that of charcoal in a well-luted crucible, which, though long kept in a strong fire, comes out unconsumed.

An easy experiment will satisfy any one of this conserving power of flame enveloping red coal. Take a small stick of deal or other wood, the size of a goose-quill, and hold it horizontally and steadily in the flame of the candle above the wick, without touching it, but in the body of the flame. The wood will first be inflamed, and burn beyond the edge of the flame of the candle, perhaps a quarter of an inch. When the flame of the wood goes out, it will leave a red coal at the end of the stick, part of which will be in the flame of the candle, and part out in the air. In a minute or two you will perceive the coal in the air diminish gradually, so as to form a neck; while the part in the flame continues of its first size, and at the neck being quite consumed, it drops off; and by rolling it between your fingers when extinguished, you will find it still a solid coal.

However, as one cannot be always putting on fresh fuel in this stove to furnish a continual flame as is done in a candle, the air in the intervals of time gets at the red coals and consumes them.

Yet the conservation while it lasted, so much delayed the consumption of the coals, that two fires, one made in the morning, and the other in the afternoon, each made by only a hatful of coals, were sufficient to keep my writing-room, about sixteen feet square and ten high, warm a whole day. The fire kindled at seven in the morning would burn till noon; and all the iron of the machine with the walls of the niche being thereby heated, the room kept warm till evening, when another smaller fire kindled, kept it warm till midnight.

Instead of the sliding plate E, which shuts the front of the box C, I sometimes used another which had a pane of glass, or, which is better, of Muscovy talc, that the flame might be seen descending from the bottom of the vase and passing in a column through the box C into the cavities of the bottom plate, like water falling from a funnel, admirable to such as are not acquainted with the nature of the machine, and in itself a pleasing spectacle.

Every utensil, however properly contrived to serve its purpose, requires some practice before it can be used adroitly. Put into the hands of a man for the first time a gimblet or a hammer (very simple instruments), and tell him the use of them, he shall neither bore a hole nor drive a nail with the dexterity and success of another who has been accustomed to handle them. The beginner there-

fore in the use of this machine, will do well not to be discouraged with little accidents that may arise at first from his want of experience. Being somewhat complex, it requires, as already said, a variety of attentions; habit will render them unnecessary. And the studious man who is much in his chamber, and has a pleasure in managing his own fire, will soon find this a machine most comfortable and delightful. To others who leave their fires to the care of ignorant servants, I do not recommend it. They will with difficulty acquire the knowledge necessary, and will make frequent blunders that will fill your room with smoke. It is therefore by no means fit for common use in families. It may be advisable to begin with the flaming kind of stone coal, which is large, and, not caking together, is not so apt to clog the grate. After some experience, any kind of coal may be used, and with this advantage, that no smell, even from the most sulphurous kind, can come into your room, the current of air being constantly into the vase, where too that smell is all consumed.

The vase form was chosen as being elegant in itself, and very proper for burning of coals: where wood is the usual fuel, and must be burned in pieces of some length, a long square chest may be substituted, in which (Plate VI. figure 17.) A is the cover opening by a hinge behind, B the grate, C the hearth-box with its divisions as in the other, D the plan of the chest, E the long narrow grate.

This I have not tried, but the vase machine was completed in 1771, and used by me in London three winters, and one afterwards in America, much to my satisfaction; and I have not yet thought of any improvement it may be capable of, though such may occur to others. For common use, while in France, I have contrived another grate for coals, which has in part the same property of burning the smoke and preserving the red coals longer by the flame, though not so completely as in the vase, yet sufficiently to be very useful, which I shall now describe as follows.

A (Plate VI. figure 18.) is a round grate, one foot (French) in diameter, and eight inches deep between the bars and the back; the sides and back of plate iron; the sides having holes of half an inch diameter, distant three or four inches from each other, to let in air for enlivening the fire. The back without holes. The sides do not meet at top nor at bottom by eight inches: that square is filled by grates of small bars crossing front to back to let in air below, and let out the smoke or flame above. The three middle bars of the front grate are fixed; the upper and lower may be taken out and put in at pleasure, when hot, with a pair of pincers. This round grate turns upon an axis, supported by the crotchet B, the stem of which is an inverted conical tube five inches deep, which comes on as many inches upon a pin that fits it, and which is fixed upright in a

cast iron plate D, that lies upon the hearth; in the middle of the top and bottom grates are fixed small upright pieces E E, about an inch high, which, as the whole is turned on its axis, stop it when the grate is perpendicular. Figure 19 is another view of the same machine.

In making the first fire in a morning with this grate, there is nothing particular to be observed. It is made as in other grates, the coals being put in above, after taking out the upper bar, and replacing it when they are in. The round figure of the fire, when thoroughly kindled, is agreeable; it represents the great giver of warmth to our system. As it burns down and leaves a vacancy above, which you would fill with fresh coals, the upper bar is to be taken out, and afterwards replaced. The fresh coals, while the grate continues in the same position, will throw up, as usual, a body of thick smoke. But every one accustomed to coal fires in common grates must have observed, that pieces of fresh coal, stuck in below among the red coals, have their smoke so heated as that it becomes flame as fast as it is produced, which flame rises among the coals and enlivens the appearance of the fire. Here then is the use of this swivel grate. By a push with your tongs or poker, you turn it on its pin till it faces the back of the chimney, then turn it over on its axis gently till it again faces the room, whereby all the fresh coals will be found under the live coals, and the greater part of

the smoke arising from the fresh coals will in its passage through the live ones be heated so as to be converted into flame: whence you have much more heat from them, and your red coals are longer preserved from consuming. I conceive this construction, though not so complete a consumer of all the smoke as the vase, yet to be fitter for common use, and very advantageous. It gives too a full sight of the fire, always a pleasing object, which we have not in the other. It may with a touch be turned more or less from any one of the company that desires to have less of its heat, or presented full to one just come out of the cold. And supported in a horizontal position, a tea-kettle may be boiled on it.

The author's description of his Pennsylvania fire-place, first published in 1744, having fallen into the hands of workmen in Europe, who did not, it seems, well comprehend the principles of that machine, it was much disfigured in their imitations of it; and one of its main intentions, that of admitting a sufficient quantity of fresh air warmed in entering through the air-box, nearly defeated, by a pretended improvement, in lessening its passages to make more room for coals in a grate. On pretence of such improvements, they obtained patents for the invention, and for a while made great profits by the sale, till the public became sensible of that defect, in the expected operation. If the same thing should be attempted with this vase

stove, it will be well for the buyer to examine thoroughly such pretended improvements, lest, being the mere productions of ignorance, they diminish or defeat the advantages of the machine, and produce inconvenience and disappointment.

The method of burning smoke, by obliging it to descend through hot coals, may be of great use in heating the walls of a hot-house. In the common way, the horizontal passages or flues that are made to go and return in those walls, lose a great deal of their effect when they come to be foul with soot; for a thick blanket-like lining of soot prevents much of the hot air from touching and heating the brick work in its passage, so that more fire must be made as the flue grows fouler: but by burning the smoke they are kept always clean. The same method may also be of great advantage to those businesses in which large coppers or caldrons are to be heated.

ON IMPROVEMENTS IN NAVIGATION.

TO MONS. ALPHONSE LE ROY, AT PARIS.

At sea, on board the London Packet, Capt. Truxton.

SIR, *August*, 1785.

YOUR learned writings on the navigation of the ancients, which contain a great deal of curious information, and your very ingenious contrivances for improving the modern sails, (*voilure,*) of which I saw with great pleasure a successful trial

on the river Seine, have induced me to submit to your consideration and judgment some thoughts I have had on the latter subject.

Those mathematicians who have endeavored to improve the swiftness of vessels, by calculating to find the form of least resistance, seem to have considered a ship as a body moving through one fluid only, the water; and to have given little attention to the circumstances of her moving through another fluid, the air. It is true, that when a vessel sails right before the wind, this circumstance is of no importance, because the wind goes with her; but in every deviation from that course, the resistance of the air is something, and becomes greater in proportion as that deviation increases. I waive at present the consideration of those different degrees of resistance given by the air to that part of the hull which is above water, and confine myself to that given to the sails; for their motion through the air is resisted by the air, as the motion of the hull through the water is resisted by the water, though with less force, as the air is a lighter fluid. And to simplify this discussion as much as possible, I would state one situation only, to wit, that of the wind upon the beam, the ship's course being directly across the wind: and I would suppose the sail set in an angle of 45 degrees with the keel, as in the following figure. (Plate VII. fig. 1.)

A B represents the body of the vessel, C D the position of the sail, E E E the direction of the wind;

M M the line of motion. In observing this figure it will appear, that so much of the body of the vessel as is immersed in the water must, to go forward, remove out of its way what water it meets with between the pricked lines F F. And the sail, to go forward, must move out of its way all the air its whole dimension meets with between the pricked lines C G and D G. Thus both the fluids give resistance to the motion, each in proportion to the quantity of matter contained in the dimensions to be removed. And though the air is vastly lighter than the water, and therefore more easily removed, yet the dimension being much greater its effect is very considerable.

It is true that in the case stated, the resistance given by the air between those lines to the motion of the sail, is not apparent to the eye, because the greater force of the wind, which strikes it in the direction E E E, overpowers its effect and keeps the sail full in the curve a, a, a, a, a. But suppose the wind to cease, and the vessel in a calm to be impelled with the same swiftness by oars, the sail would then appear filled in the contrary curve, b, b, b, b, b, when prudent men would immediately perceive, that the air resisted its motion, and would order it to be taken in.

Is there any possible means of diminishing this resistance, while the same quantity of sail is exposed to the action of the wind, and therefore the same force obtained from it? I think there is, and

that it may be done by dividing the sail into a number of parts, and placing those parts in a line one behind the other; thus instead of one sail extending from C to D, figure 2, if four sails, containing together the same quantity of canvas, were placed as in figure 3, each having one quarter of the dimensions of the great sail, and exposing a quarter of its surface to the wind, they would give a quarter of its force; so that the whole force obtained from the wind would be the same, while the resistance from the air would be nearly reduced to the space between the pricked lines *a b* and *c d*, before the foremost sail.

It may perhaps be doubted whether the resistance from the air would be so diminished; since possibly each of the following small sails having also air before it, which must be removed, the resistance on the whole would be the same.

This is then a matter to be determined by experiment. I will mention one that I many years since made with success for another purpose; and I will propose another small one easily made. If that too succeeds, I should think it worth while to make a larger, though at some expense, on a river boat; and perhaps time, and the improvements experience will afford, may make it applicable with advantage to larger vessels.

Having near my kitchen chimney a round hole of eight inches diameter, through which was a constant steady current of air, increasing or dimi-

nishing only as the fire increased or diminished, I contrived to place my jack so as to receive the current; and taking off the fliers, I fixed in their stead on the same pivot, a round tin plate of nearly the same diameter with the hole; and having cut it in radial lines almost to the centre, so as to have six equal vanes, I gave to each of them the obliquity of forty-five degrees. They moved round, without the weight, by the impression only of the current of air, but too slowly for the purpose of roasting. I suspected that the air struck by the back of each vane might possibly by its resistance retard the motion; and to try this, I cut each of them into two, and I placed the twelve, each having the same obliquity, in a line behind each other, when I perceived a great augmentation in its velocity, which encouraged me to divide them once more, and continuing the same obliquity, I placed the twenty-four behind each other in a line, when the force of the wind being the same, and the surface of vane the same, they moved round with much greater rapidity, and perfectly answered my purpose.

The second experiment that I propose, is to take two playing cards of the same dimensions, and cut one of them transversely into eight equal pieces; then with a needle string them upon two threads one near each end, and place them so upon the threads that, when hung up, they may be one exactly over the other, at a distance equal to their

breadth, each in a horizontal position; and let a small weight, such as a bird-shot, be hung under them, to make them fall in a straight line when let loose. Suspend also the whole card by threads from its four corners, and hang to it an equal weight, so as to draw it downwards when let fall, its whole breadth pressing against the air. Let those two bodies be attached, one of them to one end of a thread a yard long, the other to the other end. Extend a twine under the ceiling of a room, and put through it at thirty inches' distance two pins bent in the form of fish-hooks. On these two hooks hang the two bodies, the thread that connects them extending parallel to the twine, which thread being cut, they must begin to fall at the same instant. If they take equal time in falling to the floor, it is a proof that the resistance of the air is in both cases equal. If the whole card requires a longer time, it shows that the sum of the resistances to the pieces of the cut card is not equal to the resistance of the whole one.[1]

This principle so far confirmed, I would proceed to make a larger experiment with a shallop, which I would rig in this manner. Same plate, fig. 4.

A B is a long boom, from which are hoisted seven jibs, a, b, c, d, e, f, g, each a seventh part of the

[1] The motion of the vessel made it inconvenient to try this simple experiment at sea, when the proposal of it was written. But it has been tried since we came on shore, and succeeded as the other.

whole dimensions, and as much more as will fill the whole space when set in an angle of forty-five degrees, so that they may lap when going before the wind, and hold more when going large. Thus rigged, when going right before the wind, the boom should be brought at right angles with the keel, by means of the sheet ropes C D, and all the sails hauled flat to the boom.

These positions of boom and sails to be varied as the wind quarters. But when the wind is on the beam, or when you would turn to windward, the boom is to be hauled right fore and aft, and the sails trimmed according as the wind is more or less against your course.

It seems to me that the management of a shallop so rigged would be very easy, the sails being run up and down separately, so that more or less sail may be made at pleasure; and I imagine, that there being full as much sail exposed to the force of the wind which impels the vessel in its course, as if the whole were in one piece, and the resistance of the dead air against the foreside of the sail being diminished, the advantage of swiftness would be very considerable; besides that the vessel would lie nearer the wind.

Since we are on the subject of improvements in navigation, permit me to detain you a little longer with a small relative observation. Being, in one of my voyages, with ten merchant-ships under convoy of a frigate at anchor in Torbay, waiting

for a wind to go to the westward, it came fair, but brought in with it a considerable swell. A signal was given for weighing, and we put to sea all together; but three of the ships left their anchors, their cables parting just as their anchors came a-peak. Our cable held, and we got up our anchor; but the shocks the ship felt before the anchor got loose from the ground made me reflect on what might possibly have caused the breaking of the other cables; and I imagined it might be the short bending of the cable just without the hause-hole, from a horizontal to an almost vertical position, and the sudden violent jerk it receives by the rising of the head of the ship on the swell of a wave while in that position. For example, suppose a vessel hove up so as to have her head nearly over her anchor, which still keeps its hold, perhaps in a tough bottom; if it were calm, the cable still out would form nearly a perpendicular line, measuring the distance between the hause-hole and the anchor; but if there is a swell, her head in the trough of the sea will fall below the level, and when lifted on the wave will be much above it. In the first case the cable will hang loose and bend perhaps as in figure 5. In the second case, figure 6, the cable will be drawn straight with a jerk, must sustain the whole force of the rising ship, and must either loosen the anchor, resist the rising force of the ship, or break. But why does it break at the hause-hole?

Let us suppose it a cable of three inches diameter, and represented by figure 7. If this cable is to be bent round the corner A, it is evident that either the part of the triangle contained between the letters a, b, c, must stretch considerably, and those most that are nearest the surface; or, that the parts between d, e, f, must be compressed; or both, which most probably happens. In this case the lower half of the thickness affords no strength against the jerk, it not being strained; the upper half bears the whole, and the yarns near the upper surface being first and most strained, break first, and the next yarns follow; for in this bent situation they cannot bear the strain altogether, and each contributes its strength to the whole, as they do when the cable is strained in a straight line.

To remedy this, methinks it would be well to have a kind of large pulley wheel, fixed in the hause-hole, suppose of two feet diameter, over which the cable might pass; and being there bent gradually to the round of the wheel, would thereby be more equally strained, and better able to bear the jerk, which may save the anchor, and by that means in the course of the voyage to save the ship.

One maritime observation more shall finish this letter. I have been a reader of newspapers now near seventy years, and I think few years pass without an account of some vessel met with at sea, with no living soul on board, and so many feet of water in her hold, which vessel has nevertheless

been saved and brought into port: and when not met with at sea, such forsaken vessels have often come ashore on some coast. The crews, who have taken to their boats, and thus abandoned such vessels, are sometimes met with and taken up at sea by other ships, sometimes reach a coast, and are sometimes never heard of. Those that give an account of quitting their vessels generally say, that she sprung a leak, that they pumped for some time, that the water continued to rise upon them, and that, despairing to save her, they had quitted her lest they should go down with her. It seems by the event that this fear was not always well-founded, and I have endeavored to guess at the reason of the people's too hasty discouragement.

When a vessel springs a leak near her bottom, the water enters with all the force given by the weight of the column of water without, which force is in proportion to the difference of level between the water without and that within. It enters therefore with more force at first and in greater quantity, than it can afterwards when the water within is higher. The bottom of the vessel too is narrower, so that the same quantity of water coming into that narrow part, rises faster than when the space for it to flow is larger. This helps to terrify. But as the quantity entering is less and less as the surfaces without and within become more nearly equal in height, the pumps that could not keep the water

from rising at first, might afterwards be able to prevent its rising higher, and the people might have remained on board in safety, without hazarding themselves in an open boat on the wide ocean. (Same plate, fig. 8.)

Besides the greater equality in the height of the two surfaces, there may sometimes be other causes that retard the farther sinking of a leaky vessel. The rising water within may arrive at quantities of light wooden work, empty chests, and particularly empty water-casks, which if fixed so as not to float themselves may help to sustain her. Many bodies which compose a ship's cargo may be specifically lighter than water; all these when out of water are an additional weight to that of the ship, and she is in proportion pressed deeper into the water; but as soon as these bodies are immersed, they weigh no longer on the ship; but on the contrary, if fixed, they help to support her, in proportion as they are specifically lighter than the water. And it should be remembered, that the largest body of a ship may be so balanced in the water, that an ounce less or more of weight may leave her at the surface or sink her to the bottom. There are also certain heavy cargoes that, when the water gets at them, are continually dissolving, and thereby lightening the vessel, such as salt and sugar. And as to water-casks, mentioned above, since the quantity of them must be great in ships of war where the number of men consume a great deal of

water every day, if it had been made a constant rule to bung them up as fast as they were emptied, and to dispose the empty casks in proper situations, I am persuaded that many ships which have been sunk in engagements, or have gone down afterwards, might with the unhappy people have been saved; as well as many of those which in the last war foundered, and were never heard of. While on this topic of sinking, one cannot help recollecting the well-known practice of the Chinese, to divide the hold of a great ship into a number of separate chambers by partitions tight caulked, (of which you gave a model in your boat upon the Seine) so that if a leak should spring in one of them the others are not affected by it; and though that chamber should fill to a level with the sea, it would not be sufficient to sink the vessel. We have not imitated this practice. Some little disadvantage it might occasion in the stowage is perhaps one reason, though that I think might be more than compensated by an abatement in the insurance that would be reasonable, and by a higher price taken of passengers, who would rather prefer going in such a vessel. But our seafaring people are brave, despise danger, and reject such precautions of safety, being cowards only in one sense, that of *fearing* to be *thought afraid.*

I promised to finish my letter with the last observation, but the garrulity of the old man has got hold of me, and as I may never have another occa-

sion of writing on this subject, I think I may as well now, once for all, empty my nautical budget, and give you all the thoughts that have in my various long voyages occurred to me relating to navigation. I am sure that in you they will meet a candid judge, who will excuse my mistakes on account of my good intention.

There are six accidents that may occasion the loss of ships at sea. We have considered one of them, that of foundering by a leak. The other five are, 1. Oversetting by sudden flaws of wind, or by carrying sail beyond the bearing. 2. Fire by accident or carelessness. 3. A heavy stroke of lightning, making a breach in the ship, or firing the powder. 4. Meeting and shocking with other ships in the night. 5. Meeting in the night with islands of ice.

To that of oversetting, privateers in their first cruise have, as far as has fallen within my knowledge or information, been more subject than any other kind of vessels. The double desire of being able to overtake a weaker flying enemy, or to escape when pursued by a stronger, has induced the owners to overmast their cruisers, and to spread too much canvas; and the great number of men, many of them not seamen, who being upon deck when a ship heels suddenly are huddled down to leeward, and increase by their weight the effect of the wind. This therefore should be more attended to and guarded against; especially as the advan-

tage of lofty masts is problematical. For the upper sails have greater power to lay a vessel more on her side, which is not the most advantageous position for going swiftly through the water. And hence it is that vessels, which have lost their lofty masts, and been able to make little more sail afterwards than permitted the ship to sail upon an even keel, have made so much way, even under jury masts, as to surprise the mariners themselves. But there is, besides, something in the modern form of our ships that seems as if calculated expressly to allow their oversetting more easily. The sides of a ship, instead of spreading out as they formerly did in the upper works, are of late years turned in, so as to make the body nearly round, and more resembling a cask. I do not know what the advantages of this construction are, except that such ships are not easily boarded. To me it seems a contrivance to have less room in a ship at nearly the same expense. For it is evident that the same timber and plank consumed in raising the sides from a to b, and from d to c, would have raised them from a to e, and from d to f, (same plate, fig. 9.) In this form all spaces between e, a, b, and c, d, f, would have been gained, the deck would have been larger, the men would have had more room to act, and not have stood so thick in the way of the enemy's shot; and the vessel, the more she was laid down on her side, the more bearing she would meet with, and more effectual to support her, as being farther

from the centre. Whereas in the present form, her ballast makes the chief part of her bearing, without which she would turn in the sea almost as easily as a barrel. More ballast by this means becomes necessary, and that sinking a vessel deeper in the water occasions more resistance to her going through it. The Bermudian sloops still keep with advantage to the old spreading form. The islanders in the great Pacific ocean, though they have no large ships, are the most expert boat-sailors in the world, navigating that sea safely with their proas, which they prevent oversetting by various means. Their sailing proas for this purpose have outriggers, generally to windward, above the water, on which one or more men are placed, to move occasionally further from or nearer to the vessel as the wind freshens or slackens. But some have their outriggers to leeward, which, resting on the water, support the boat so as to keep her upright when pressed down by the wind. Their boats moved by oars, or rather paddles, are for long voyages, fixed two together by cross bars of wood that keep them at some distance from each other, and so render their oversetting next to impossible. How far this may be practicable in larger vessels, we have not yet sufficient experience. I know of but one trial made in Europe, which was about one hundred years since, by Sir William Petty. He built a double vessel, to serve as a packet boat between England and Ireland.

Her model still exists in the museum of the Royal Society, where I have seen it. By the accounts we have of her, she answered well the purpose of her construction, making several voyages; and though wrecked at last by a storm, the misfortune did not appear owing to her particular construction, since many other vessels of the common form were wrecked at the same time. The advantage of such a vessel is, that she needs no ballast, therefore swims either lighter or will carry more goods; and that passengers are not so much incommoded by her rolling: to which may be added, that if she is to defend herself by her cannon, they will probably have more effect, being kept more generally in a horizontal position, than those in common vessels. I think, however, that it would be an improvement of that model, to make the sides which are opposed to each other perfectly parallel, though the other sides are formed as in common; thus, figure 10.

The building of a double ship would indeed be more expensive in proportion to her burthen; and that perhaps is sufficient to discourage the method.

The accident of fire is generally well guarded against by the prudent captain's strict orders against smoking between decks, or carrying a candle there out of a lantern. But there is one dangerous practice which frequent terrible accidents resulting therefrom have not yet been sufficient to

abolish; that of carrying store-spirits to sea in casks. Two large ships, the Serapis and the Duke of Athol, one an East-Indiaman, the other a frigate, have been burnt within these two last years, and many lives miserably destroyed, by drawing spirits out of a cask near a candle. It is high time to make it a general rule, that no spirits shall be drawn by light of candle.

The misfortune by a stroke of lightning I have in my former writings endeavored to show a method of guarding against, by a chain and pointed rod, extending, when run up, from above the top of the mast to the sea. These instruments are now made and sold at a reasonable price by Nairne & Co. in London, and there are several instances of success attending the use of them. They are kept in a box, and may be run up and fixed in about five minutes, on the apparent approach of a thunder gust.

Of the meeting and shocking with other ships in the night I have known two instances in voyages between London and America. In one both ships arrived, though much damaged, each reporting their belief that the other must have gone to the bottom. In the other, only one got to port; the other was never afterwards heard of. These instances happened many years ago, when the commerce between Europe and America was not a tenth part of what it is at present; ships of course thinner scattered, and the chance of meeting pro-

portionably less. It has long been the practice to keep a *look-out before* in the channel, but at sea it has been neglected. If it is not at present thought worth while to take that precaution, it will in time become of more consequence; since the number of ships at sea is continually augmenting. A drum frequently beat, or a bell rung in a dark night, might help to prevent such accidents.

Islands of ice are frequently seen off the banks of Newfoundland, by ships going between North America and Europe. In the day time they are easily avoided, unless in a very thick fog. I remember two instances of ships running against them in the night. The first lost her bowsprit, but received little other damage. The other struck where the warmth of the sea had wasted the ice next to it, and a part hung over above. This perhaps saved her, for she was under great way; but the upper part of the cliff taking her fore-topmast, broke the shock, though it carried away the mast. She disengaged herself with some difficulty, and got safe into port; but the accident shows the possibility of other ships being wrecked and sunk by striking those vast masses of ice, of which I have seen one that we judged to be seventy feet high above the water, consequently eight times as much under water; and it is another reason for keeping a good *look-out before*, though far from any coast that may threaten danger."

It is remarkable, that the people we consider as

savages have improved the art of sailing and rowing boats, in several points, beyond what we can pretend to. We have no sailing-boats equal to the flying proas of the South Seas; no rowing or paddling-boat equal to that of the Greenlanders for swiftness and safety. The birch canoes of the North-American Indians have also some advantageous properties. They are so light that two men may carry one of them over land, which is capable of carrying a dozen upon the water; and, in heeling, they are not so subject to take in water as our boats, the sides of which are lowest in the middle, where it is most likely to enter, this being highest in that part, as in figure 11.

The Chinese are an enlightened people, the most anciently civilised of any existing; and their arts are ancient, a presumption in their favor: their method of rowing their boats differs from ours, the oars being worked either two a-stern as we scull, or on the sides, with the same kind of motion, being hung parallel to the keel on a rail, and always acting in the water, not perpendicular to the side as ours are, nor lifted out at every stroke, which is a loss of time, and the boat, in the interval, loses motion. They see our manner, and we theirs, but neither are disposed to learn of or copy the other.

To the several means of moving boats mentioned above, may be added the singular one lately exhibited at Javelle, on the Seine below Paris, where a clumsy boat was moved across that river in three

minutes by rowing, not in the water, but in the air, that is, by whirling round a set of windmill vanes fixed to a horizontal axis, parallel to the keel, and placed at the head of the boat. The axis was bent into an elbow at the end, by the help of which it was turned by one man at a time. I saw the operation at a distance. The four vanes appeared to be about five feet long, and perhaps two and an half wide. The weather was calm. The labor appeared to be great for one man, as the two several times relieved each other. But the action upon the air by the oblique surfaces of the vanes must have been considerable, as the motion of the boat appeared tolerably quick going and returning; and she returned to the same place whence she first set out, notwithstanding the current. This machine is since applied to the moving of air-balloons: an instrument similar may be contrived to move a boat by turning under water.

Several mechanical projectors have at different times proposed to give motion to boats, and even to ships, by means of circular rowing, or paddles placed on the circumference of wheels, to be turned constantly on each side of the vessel; but this method, though frequently tried, has never been found so effectual as to encourage a continuance of the practice. I do not know that the reason has hitherto been given. Perhaps it may be this, that great part of the force employed contributes little to the motion. For instance, (fig. 12.) of the

four paddles a, b, c, d, all under water, and turning to move a boat from X to Y, c has the most power, b nearly, though not quite as much, their motion being nearly horizontal; but the force employed in moving a, is consumed in pressing almost downright upon the water till it comes to the place of b; and the force employed in moving d is consumed in lifting the water till d arrives at the surface; by which means much of the labor is lost. It is true, that by placing the wheels higher out of the water, this waste labor will be diminished in a calm, but where a sea runs, the wheels must unavoidably be often dipt deep in the waves, and the turning of them thereby rendered very laborious to little purpose.

Among the various means of giving motion to a boat, that of M. Bernoulli appears one of the most singular, which was to have fixed in the boat a tube in the form of an L, the upright part to have a funnel-kind of opening at top, convenient for filling the tube with water; which, descending and passing through the lower horizontal part, and issuing in the middle of the stern, but under the surface of the river, should push the boat forward. There is no doubt that the force of the descending water would have a considerable effect, greater in proportion to the height from which it descended; but then it is to be considered, that every bucket full pumped or dipped up into the boat, from its' side or through its bottom, must

have its *vis inertiæ* overcome so as to receive the motion of the boat, before it can come to give motion by its descent; and that will be a deduction from the moving power. To remedy this, I would propose the addition of another such L pipe, and that they should stand back to back in the boat thus, (Plate VII. fig. 13;) the forward one being worked as a pump, and sucking in the water at the head of the boat, would draw it forward while pushed in the same direction by the force at the stern. And after all, it should be calculated whether the labor of pumping would be less than that of rowing. A fire-engine might possibly in some cases be applied in this operation with advantage.

Perhaps this labor of raising water might be spared, and the whole force of a man applied to the moving of a boat, by the use of air instead of water. Suppose the boat constructed in this form, (Plate VII. fig. 14:) A a tube round or square, of two feet in diameter, in which a piston may move up and down: the piston to have valves in it, opening inwards, to admit air when the piston rises; and shutting, when it is forced down by means of the lever B turning on the centre C. The tube to have a valve D, to open when the piston is forced down, and let the air pass out at E, which striking forcibly against the water abaft, must push the boat forward. If there is added an air-vessel F, properly valved and placed, the

force would continue to act while a fresh stroke is taken with the lever. The boatman might stand with his back to the stern, and putting his hands behind him, work the motion by taking hold of the cross bar at B, while another should steer; or if he had two such pumps, one on each side of the stern, with a lever for each hand, he might steer himself by working occasionally more or harder with either hand, as watermen now do with a pair of sculls. There is no position in which the body of a man can exert more strength than in pulling right upwards. To obtain more swiftness, greasing the bottom of a vessel is sometimes used, and with good effect. I do not know that any writer has hitherto attempted to explain this. At first sight one would imagine, that though the friction of a hard body, sliding on another hard body, and the resistance occasioned by that friction, might be diminished by putting grease between them; yet that a body sliding on a fluid, such as water, should have no need of, nor receive any advantage from such greasing. But the fact is not disputed. And the reason perhaps may be this—The particles of water have a mutual attraction, called the attraction of adhesion. Water also adheres to wood, and to many other substances, but not to grease: on the contrary, they have a mutual repulsion; so that it is a question, whether, when oil is poured on water, they ever actually touch each other; for a drop

of oil upon water, instead of sticking to the spot where it falls, as it would if it fell on a looking-glass, spreads instantly to an immense distance in a film extremely thin, which it could not easily do if it touched and rubbed, or adhered even in a small degree, to the surface of the water. Now the adhesive force of water to itself, and to other substances, may be estimated from the weight of it necessary to separate a drop which adheres, while growing, till it has weight enough to force the separation and break the drop off. Let us suppose the drop to be the size of a pea, then there will be as many of these adhesions as there are drops of that size touching the bottom of a vessel, and these must be broken by the moving power, every step of her motion that amounts to a drop's breadth: and there being no such adhesions to break between the water and a greased bottom, may occasion the difference.

So much respecting the motion of vessels. But we have sometimes occasion to stop their motion; and if a bottom is near enough we can cast anchor: where there are no soundings, we have as yet no means to prevent driving in a storm, but by lying-to, which still permits driving at the rate of about two miles an hour; so that, in a storm continuing fifty hours, which is not an uncommon case, the ship may drive one hundred miles out of her course; and should she in that distance meet with a lee-shore, she may be lost.

To prevent this driving to leeward in deep water, a swimming anchor is wanting, which ought to have these properties:

1. It should have a surface so large as, being at the end of a hauser in the water, and placed perpendicularly, should hold so much of it, as to bring the ship's head to the wind, in which situation the wind has least power to drive her.

2. It should be able by its resistance to prevent the ship's receiving way.

3. It should be capable of being situated below the heave of the sea, but not below the undertow.

4. It should not take up much room in the ship.

5. It should be easily thrown out, and put into its proper situation.

6. It should be easy to take in again, and stow away.

An ingenious old mariner, whom I formerly knew, proposed, as a swimming anchor for a large ship, to have a stem of wood, twenty-five feet long and four inches square, with four boards of 18, 16, 14, and 12 feet long, and one foot wide, the boards to have their substance thickened several inches in the middle by additional wood, and to have each a four inch square hole through its middle, to permit its being slipped on occasionally upon the stem, and at right angles with it; where all being placed and fixed at four feet distance from each other, it would have the appearance of the old mathematical instrument called a forestaff.

This thrown into the sea, and held by a hauser veered out at some length, he conceived would bring a vessel up, and prevent her driving, and when taken in, might be stowed away by separating the boards from the stem. Figure 15. Probably such a swimming anchor would have some good effect; but it is subject to this objection, that lying on the surface of the sea, it is liable to be hove forward by every wave, and thereby give so much leave for the ship to drive.

Two machines for this purpose have occurred to me, which, though not so simple as the above, I imagine would be more effectual, and more easily manageable. I will endeavor to describe them, that they may be submitted to your judgment, whether either would be serviceable; and if they would, to which we should give the preference.

The first is to be formed, and to be used in the water, on almost the same principles with those of a paper kite used in the air. Only as the paper kite rises in the air, this is to descend in the water. Its dimensions will be different for ships of different size.

To make one of suppose fifteen feet high; take a small spar of that length for the back-bone, A B, Plate VII. figure 16; a smaller of half that length, C D, for the cross piece. Let these be united by a bolt at E, yet so as that by turning on the bolt they may be laid parallel to each other. Then

make a sail of strong canvas, in the shape of figure 17. To form this, without waste of sail-cloth, sew together pieces of the proper length, and for half the breadth, as in figure 18, then cut the whole in the diagonal lines, a, b, c, and turn the piece F so as to place its broad part opposite to that of the piece G, and the piece H in like manner opposite to I, which, when all sewed together, will appear as in fig. 17. This sail is to be extended on the cross of fig. 16, the top and bottom points well secured to the ends of the long spar; the two side points d, e, fastened to the ends of two cords, which coming from the angle of the loop (which must be similar to the loop of a kite) pass through two rings at the ends of the short spar, so as that on pulling upon the loop the sail will be drawn to its extent. The whole may, when on board, be furled up, as in figure 19, having a rope from its broad end, to which is tied a bag of ballast for keeping that end downwards when in the water, and at the other end another rope, with an empty keg at its end, to float on the surface; this rope long enough to permit the kites' descending into the undertow, or if you please, lower into still water. It should be held by a hauser. To get it home easily, a small loose rope may be veered out with it, fixed to the keg. Hauling on that rope will bring the kite home with small force, as it will then come end-ways.

It seems probable that such a kite at the end of

a long hauser would keep a ship with her head to the wind; and, resisting every tug, would prevent her driving so fast as when her side is exposed to it, and nothing to hold her back. If only half the driving is prevented, so as that she moves but fifty miles instead of the hundred during a storm, it may be some advantage, both in holding so much distance as is saved, and in keeping from a lee-shore. If single canvas should not be found strong enough to bear the tug without splitting, it may be doubled, or strengthened by a netting behind it, represented by figure 20.

The other machine for the same purpose, is to be made more in the form of an umbrella, as represented, figure 21. The stem of the umbrella, a square spar of proper length, with four moveable arms, of which two are represented C, C, figure 22. These arms to be fixed in four joint cleats, as D, D, &c. one on each side of the spar, but so as that the four arms may open by turning on a pin in the joint. When open they form a cross, on which a four-square canvas sail is to be extended, its corners fastened to the ends of the four arms. Those ends are also to be stayed by ropes fastened to the stem or spar, so as to keep them short of being at right angles with it: and to the end of one of the arms should be hung the small bag of ballast, and to the end of the opposite arm the empty keg. This, on being thrown into the sea, would immediately open; and when it had per-

formed its function, and the storm over, a small rope from its other end being pulled on, would turn it, close it, and draw it easily home to the ship. This machine seems more simple in its operation, and more easily manageable than the first, and perhaps may be as effectual.[1]

Vessels are sometimes retarded, and sometimes forwarded in their voyages, by currents at sea, which are often not perceived. About the year 1769, or 70, there was an application made by the board of customs at Boston, to the lords of the treasury in London, complaining that the packets between Falmouth and New York were generally a fortnight longer in their passages than merchant-ships from London to Rhode Island, and proposing that for the future they should be ordered to Rhode Island, instead of New York. Being then concerned in the management of the American post-office, I happened to be consulted on the occasion; and it appearing strange to me that there should be such a difference between two places, scarce a day's run asunder, especially when the merchant-ships are generally deeper laden, and more weakly manned than the packets, and had from London the whole length of the river and channel to run before they left the land

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[1] Captain Truxton, on board whose ship this was written, executed this proposed machine: he gave six arms to the umbrella, and joined them to the stem by iron hinges: the canvas was double. He took it with him to China in 1786.

of England, while the packets had only to go from Falmouth, I could not but think the fact misunderstood or misrepresented. There happened then to be in London a Nantucket sea-captain of my acquaintance, to whom I communicated the affair. He told me he believed the fact might be true; but the difference was owing to this, that the Rhode Island captains were acquainted with the gulph stream, which those of the English packets were not. We are well acquainted with that stream, said he, because in our pursuit of whales, which keep near the sides of it, but are not to be met with in it, we run down along the sides, and frequently cross it to change our side; and in crossing it have sometimes met and spoken with those packets, who were in the middle of it, and stemming it. We have informed them that they were stemming a current that was running against them at the rate of three miles an hour, and advised them to cross it and get out of it; but they were too wise to be counselled by simple American fishermen. When the winds are but light, he added, they are carried back by the current more than they are forwarded by the wind: and if the wind is good, the subtraction of 70 miles a-day from their course is of some importance. I then observed it was a pity no notice was taken of this current upon the charts, and requested him to mark it out for me, which he readily complied with, adding directions for avoid-

ing it in sailing from Europe to North America. I procured it to be engraved by order from the general post-office, on the old chart of the Atlantic, at Mount and Page's, Tower-hill; and copies were sent down to Falmouth for the captains of the packets, who however slighted it; but it is since printed in France, of which edition I hereto annex a copy.[1]

This stream is probably generated by the great accumulation of water on the eastern coast of America, between the tropics, by the trade-winds which constantly blow there. It is known that a large piece of water ten miles broad, and generally only three feet deep, has by a strong wind had its water driven to one side, and sustained so as to become six feet deep, while the windward side was laid dry. This may give some idea of the quantity heaped up on the American coast, and the reason of its running down in a strong current through the islands into the bay of Mexico, and thence issuing through the Gulph of Florida, and proceeding along the coast to the banks of Newfoundland, where it turns off towards and runs down through the Western Islands. Having since crossed this stream several times, in passing between America and Europe, I have been atten-

[1] The map is constructed so as to embrace in one view, the theory of the Gulph Stream and the theory of the migration of fish; some attention has been paid also to Volney's suggestions on the subject of the Gulph Stream. See the plate.

tive to sundry circumstances relating to it, by which to know when one is in it; and besides the gulph weed by which it is interspersed, I find that it is always warmer than the sea on either side of it, and that it does not sparkle in the night. I annex hereto the observations made with the thermometer in two voyages,[1] and possibly may add a third. It will appear from them, that the thermometer may be an useful instrument to a navigator, since currents coming from the northward into southern seas, will probably be found colder than the water of those seas, as the currents from southern seas into northern are found warmer. And it is not to be wondered that so vast a body of deep warm water, several leagues wide, coming from between the tropics, and issuing out of the gulph into the northern seas, should retain its warmth longer than the twenty or thirty days required to its passing the banks of Newfoundland. The quantity is too great, and it is too deep to be suddenly cooled by passing under a cooler air. The air immediately over it, however, may receive so much warmth from it as to be rarefied and rise, being rendered lighter than the air on each side of the stream; hence those airs must flow in to supply the place of the rising warm air, and, meeting each other, form those tornadoes and waterspouts frequently met with, and seen near and

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[1] See page 479.

over the stream; and as the vapor from a cup of tea in a warm room, and the breath of an animal in the same room, are hardly visible, but become sensible immediately when out in the cold air, so the vapor from the gulph stream, in warm latitudes, is scarcely visible; but when it comes into the cool air from Newfoundland, it is condensed into the fogs, for which those parts are so remarkable.

The power of wind to raise water above its common level in the sea, is known to us in America, by the high tides occasioned in all our seaports when a strong north-easter blows against the gulph stream.

The conclusion from these remarks is, that a vessel from Europe to North America may shorten her passage by avoiding to stem the stream, in which the thermometer will be very useful; and a vessel from America to Europe may do the same by the same means of keeping in it. It may have often happened accidentally, that voyages have been shortened by these circumstances. It is well to have the command of them.

But may there not be another cause, independent of winds and currents, why passages are generally shorter from America to Europe than from Europe to America? This question I formerly considered in the following short paper.

On board the Pennsylvania Packet, Captain Osborne.

At sea, April 5, 1775.

"Suppose a ship to make a voyage eastward from a place in lat. 40° north, to a place in lat. 50° north, distance in longitude 75 degrees.

"In sailing from 40 to 50, she goes from a place where a degree of longitude is about eight miles greater than in the place she is going to. A degree is equal to four minutes of time; consequently the ship in the harbor she leaves, partaking of the diurnal motion of the earth, moves two miles in a minute faster, than when in the port she is going to; which is 120 miles in an hour.

"This motion in a ship and cargo is of great force; and if she could be lifted up suddenly from the harbor in which she lay quiet, and set down instantly in the latitude of the port she was bound to, though in a calm, that force contained in her would make her run a great way at a prodigious rate. This force must be lost gradually in her voyage, by gradual impulse against the water, and probably thence shorten the voyage. Query: In returning does the contrary happen, and is her voyage thereby retarded and lengthened?"[1]

Would it not be a more secure method of planking ships, if, instead of thick single planks laid

[1] Since this paper was read at the Society in Philadelphia, an ingenious member, Mr. Patterson, convinced the writer that the returning voyage would not, from this cause, be retarded.

horizontally, we were to use planks of half the thickness, and lay them double and across each other as in Plate VII. figure 23? To me it seems that the difference of expense would not be considerable, and that the ship would be both tighter and stronger.

The securing of the ship is not the only necessary thing; securing the health of the sailors, a brave and valuable order of men, is likewise of great importance. With this view, the methods so successfully practised by Captain Cook in his long voyages, cannot be too closely studied or carefully imitated. A full account of those methods is found in Sir John Pringle's speech, when the medal of the Royal Society was given to that illustrious navigator. I am glad to see in his last voyage that he found the means effectual which I had proposed for preserving flour, bread, &c. from moisture and damage. They were found dry and good after being at sea four years. The method is described in my philosophical works, page 452, fifth edition.[1]

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[1] TO MR. P. FRANKLIN, NEWPORT, RHODE ISLAND.

Best Method of securing a Powder Magazine from Lightning—Preserving Powder, Flour, &c.

——— You may acquaint the gentleman that desired you to inquire my opinion of the best method of securing a powder magazine from lightning, that I think they cannot do better than to erect a mast not far from it, which may reach fifteen or twenty feet above the top of it, with a thick iron rod, in one piece, fastened to it, pointed at the highest end, and reaching down through the

In the same, page 469, 470, is proposed a means

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earth till it comes to water. Iron is a cheap metal; but if it were dearer, as this is a public thing, the expense is insignificant; therefore I would have the rod at least an inch thick, to allow for its gradually wasting by rust; it will last as long as the mast, and may be renewed with it. The sharp point for five or six inches should be gilt.

But there is another circumstance of importance to the strength, goodness, and usefulness of the powder, which does not seem to have been enough attended to. I mean, the keeping it perfectly dry. For want of a method of doing this, much is spoiled in damp magazines, and much so damaged as to become of little value.—If, instead of barrels, it were kept in cases of bottles well corked, or in large tin canisters, with small covers shutting close by means of oiled paper between, or covering the joining on the canister; or if in barrels, then the barrels lined with thin sheet lead; no moisture in either of these methods could possibly enter the powder, since glass and metals are both impervious to water.

By the latter of these means you see tea is brought dry and crisp from China to Europe, and thence to America, though it comes all the way by sea, in the damp hold of a ship. And by this method, grain, meal, &c. if well dried before it is put up, may be kept for ages sound and good.

There is another thing very proper to line small barrels with; it is what they call tin-foil, or leaf-tin, being tin milled between rollers till it becomes as thin as paper, and more pliant, at the same time that its texture is extremely close. It may be applied to the wood with common paste, made with boiling water thickened with flour; and, so laid on, will lie very close and stick well: but I should prefer a hard sticky varnish for that purpose, made of linseed oil much boiled. The heads might be lined separately, the tin wrapping a little round their edges. The barrel, while the lining is laid on, should have the end hoops

of allaying thirst in case of want of fresh water.[1]

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slack, so that the staves standing at a little distance from each other, may admit the head into its groove. The tin-foil should be plyed into the groove. Then, one head being put in, and that end hooped tight, the barrel would be fit to receive the powder, and when the other head is put in and the hoops drove up, the powder would be safe from moisture even if the barrel were kept under water. This tin-foil is but about eighteen pence sterling a pound, and is so extremely thin, that I imagine a pound of it would line three or four powder-barrels.

I am, &c. B. FRANKLIN.

[1] *Salt Water rendered fresh by Distillation.—Method of relieving Thirst by Sea Water.*

TO MISS STEVENSON.

Craven-street, August 10, 1761.

In yours of May 19, which I have before me, you speak of the ease with which salt water may be made fresh by distillation, supposing it to be, as I had said, that in evaporation the air would take up water, but not the salt that was mixed with it. It is true that distilled sea water will not be salt; but there are other disagreeable qualities that rise with the water in distillation; which indeed several, besides Dr. Hales, have endeavored by some means to prevent; but as yet their methods have not been brought much into use.

I have a singular opinion on this subject, which I will venture to communicate to you, though I doubt you will rank it among my whims. It is certain that the skin has *imbibing* as well as *discharging* pores; witness the effects of a blistering plaister, &c. I have read that a man, hired by a physician to stand by way of experiment in the open air naked during a moist night, weighed near three pounds heavier in the morning. I have often observed myself, that however thirsty I may have been before going into the water to swim, I am never long so in the water. These imbibing pores, however, are very fine, perhaps fine enough

This has since been practised in two instances with success. Happy if their hunger, when the other provisions are consumed, could be relieved as commodiously; and perhaps in time this may be found not impossible. An addition might be made to their present vegetable provision, by drying various roots in slices by the means of an oven. The sweet potatoe of America and Spain is excellent for this purpose. Other potatoes, with carrots, parsnips, and turnips, might be prepared and preserved in the same manner.

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in filtering, to separate salt from water; for though I have soaked (by swimming, when a boy) several hours in the day for several days successively, in salt water, I never found my blood and juices salted by that means, so as to make me thirsty or feel a salt taste in my mouth: and it is remarkable, that the flesh of sea fish, though bred in salt water, is not salt. Hence I imagine, that if people at sea, distressed by thirst, when their fresh water is unfortunately spent, would make bathing tubs of their empty water casks, and, filling them with sea water, sit in them an hour or two each day, they might be greatly relieved. Perhaps keeping their clothes constantly wet might have an almost equal effect; and this without danger of catching cold. Men do not catch cold by wet clothes at sea. Damp, but not wet linen, may possibly give colds; but no one catches cold by bathing, and no clothes can be wetter than water itself. Why damp clothes should then occasion colds, is a curious question, the discussion of which I reserve for a future letter, or some future conversation.

Adieu, my little philosopher. Present my respectful compliments to the good ladies your aunts, and to Miss Pitt; and believe me ever your affectionate friend, and humble servant,

B. FRANKLIN.

With regard to make-shifts in cases of necessity, seamen are generally very ingenious themselves. They will excuse however the mention of two or three. If they happen in any circumstance, such as after ship-wreck, taking to their boat, or the like, to want a compass, a fine sewing-needle laid on clear water in a cup will generally point to the north, most of them being a little magnetical, or may be made so by being strongly rubbed or hammered, lying in a north and south direction. If their needle is too heavy to float by itself, it may be supported by little pieces of cork or wood. A man who can swim, may be aided in a long traverse by his handkerchief formed into a kite, by two cross sticks extending to the four corners; which, being raised in the air when the wind is fair and fresh, will tow him along, while lying on his back. Where force is wanted to move a heavy body, and there are but few hands and no machines, a long and strong rope may make a powerful instrument. Suppose a boat is to be drawn up on a beach, that she may be out of the surf; a stake drove into the beach where you would have the boat drawn, and another to fasten the end of the rope to, which comes from the boat, and then applying what force you have to pull upon the middle of the rope at right angles with it, the power will be augmented in proportion to the length of rope between the posts. The rope being fastened to the stake A, and drawn upon in the direction

C D, will slide over the stake B; and when the rope is bent to the angle A D B, represented by the pricked line in Plate VII. figure 24, the boat will be at B.

Some sailors may think the writer has given himself unnecessary trouble in pretending to advise them; for they have a little repugnance to the advice of landmen, whom they esteem ignorant and incapable of giving any worth notice; though it is certain that most of their instruments were the invention of landmen. At least the first vessel ever made to go on the water was certainly such. I will therefore add only a few words more, and they shall be addressed to passengers.

When you intend a long voyage, you may do well to keep your intention as much as possible a secret, or at least the time of your departure; otherwise you will be continually interrupted in your preparations by the visits of friends and acquaintance, who will not only rob you of the time you want, but put things out of your mind, so that when you come to sea, you have the mortification to recollect points of business that ought to have been done, accounts you intended to settle, and conveniencies you had proposed to bring with you, &c., all which have been omitted through the effect of these officious friendly visits. Would it not be well, if this custom could be changed; if the voyager, after having without interruption made all his preparations, should use some of the time he has

left, in going himself to take leave of his friends at their own houses, and let them come to congratulate him on his happy return.

It is not always in your power to make a choice in your captain, though much of your comfort in the passage may depend on his personal character, as you must for so long a time be confined to his company, and under his direction; if he is a sensible, sociable, good-natured, obliging man, you will be so much the happier. Such there are; but if he happens to be otherwise, and is only skilful, careful, watchful, and active in the conduct of his ship, excuse the rest, for these are the essentials.

Whatever right you have by agreement in the mass of stores laid in by him for the passengers, it is good to have some particular things in your own possession, so as to be always at your own command.

1. Good water, that of the ship being often bad. You can be sure of having it good only by bottling it from a clear spring or well and in clean bottles. 2. Good tea. 3. Coffee ground. 4. Chocolate. 5. Wine of the sort you particularly like, and cyder. 6. Raisins. 7. Almonds. 8. Sugar. 9. Capillaire. 10. Lemons. 11. Jamaica spirits. 12. Eggs greased. 13. Diet bread. 14. Portable soup. 15. Rusks. As to fowls, it is not worth while to have any called yours, unless you could have the feeding and managing of them, according to your own judgment under your own eye. As they are generally treated

at present in ships, they are for the most part sick, and their flesh tough and hard as whit-leather. All seamen have an opinion, broached I suppose at first prudently, for saving of water when short, that fowls do not know when they have drunk enough, and will kill themselves if you give them too much; so they are served with a little only once in two days. This is poured into troughs that lie sloping, and therefore immediately runs down to the lower end. There the fowls ride upon one another's backs to get at it, and some are not happy enough to reach and once dip their bills in it. Thus tantalised and tormented with thirst, they cannot digest their dry food; they fret, pine, sicken, and die. Some are found dead and thrown overboard every morning, and those killed for the table are not eatable. Their troughs should be in little divisions, like cups, to hold the water separately, figure 25. But this is never done. The sheep and hogs are therefore your best dependence for fresh meat at sea, the mutton being generally tolerable, and the pork excellent.

It is possible your captain may have provided so well in the general stores, as to render some of the particulars above recommended of little or no use to you. But there are frequently in the ship poorer passengers, who are taken at a lower price, lodge in the steerage, and have no claim to any of the cabin provisions, or to any but those kinds that are allowed the sailors. These people are

sometimes dejected, sometimes sick; there may be women and children among them. In a situation where there is no going to market to purchase such necessaries, a few of your superfluities distributed occasionally, may be of great service, restore health, save life, make the miserable happy, and thereby afford you infinite pleasure.

The worst thing in ordinary merchant ships is the cookery. They have no professed cook, and the worst hand as a seaman is appointed to that office, in which he is not only very ignorant but very dirty. The sailors have therefore a saying, that *God sends meat and the devil cooks.* Passengers more piously disposed, and willing to believe heaven orders all things for the best, may suppose, that, knowing the sea-air and constant exercise by the motion of the vessel would give extraordinary appetites, bad cooks were kindly sent to prevent our eating too much; or that, foreseeing that we should have bad cooks, good appetites were furnished to prevent our starving. If you cannot trust to these circumstances, a spirit lamp, with a blaze-pan, may enable you to cook some little things for yourself; such as a hash, a soup, &c. And it might be well also to have among your stores some potted meats, which, if well put up, will keep long good. A small tin oven, to place with the open side before the fire, may be another good utensil, in which your own servant may roast for you a bit of pork or mutton. You will sometimes

be induced to eat of the ship's salt beef, as it is often good. You will find cyder the best quencher of that thirst which salt meat or fish occasions. The ship biscuit is too hard for some sets of teeth. It may be softened by toasting. But rusk is better: for being made of good fermented bread, sliced and baked a second time, the pieces imbibe the water easily, soften immediately, digest more kindly, and are therefore more wholesome than the unfermented biscuit. By the way, rusk is the true original biscuit, so prepared to keep for sea, biscuit in French signifying twice baked. If your dry peas boil hard, a two-pound iron shot put with them into the pot, will, by the motion of the ship, grind them as fine as mustard.

The accidents I have seen at sea with large dishes of soup upon a table, from the motion of the ship, have made me wish that our potters or pewterers would make soup dishes in divisions, like a set of small bowls united together, each containing about sufficient for one person, in some such form as fig. 26; for then, when the ship should make a sudden heel, the soup would not in a body flow over one side, and fall into people's laps and scald them, as is sometimes the case, but would be retained in the separate divisions, as in figure 27.

After these trifles, permit the addition of a few general reflections. Navigation, when employed in supplying necessary provision to a country in want, and thereby preventing famines, which were

more frequent and destructive before the invention of that art, is undoubtedly a blessing to mankind. When employed merely in transporting superfluities, it is a question whether the advantage of the employment it affords is equal to the mischief of hazarding so many lives on the ocean. But when employed in pillaging merchants and transporting slaves, it is clearly the means of augmenting the mass of human misery. It is amazing to think of the ships and lives risked in fetching tea from China, coffee from Arabia, sugar and tobacco from America, all which our ancestors did well without. Sugar employs near one thousand ships, tobacco almost as many. For the utility of tobacco there is little to be said; and for that of sugar, how much more commendable would it be, if we could give up the few minutes' gratification afforded once or twice a-day by the taste of sugar in our tea, rather than encourage the cruelties exercised in producing it! An eminent French moralist says, that when he considers the wars we excite in Africa to obtain slaves, the numbers necessarily slain in those wars, the many prisoners who perish at sea by sickness, bad provisions, foul air, &c. &c. in the transportation, and how many afterwards die from the hardships of slavery, he cannot look on a piece of sugar without conceiving it stained with spots of human blood! had he added the consideration of the wars we make to take and retake the sugar islands from one another, and the

fleets and armies that perish in those expeditions, he might have seen his sugar not merely spotted, but thoroughly dyed scarlet in grain. It is these wars that make the maritime powers of Europe, the inhabitants of London and Paris, pay dearer for sugar than those of Vienna, a thousand miles from the sea; because their sugar costs not only the price they pay for it by the pound, but all they pay in taxes to maintain the fleets and armies that fight for it.[1]

With great esteem, I am, Sir, your most obedient humble servant, B. FRANKLIN.

ON THE GULPH STREAM.

Remarks on the Navigation from Newfoundland to New York, in order to avoid the Gulph Stream on one hand, and on the other the Shoals that lie to the southward of Nantucket and of St. George's Banks. [*See Plate.*]

AFTER you have passed the banks of Newfoundland in about the 44th degree of latitude, you will meet with nothing till you draw near the Isle of Sables, which we commonly pass in latitude 43. Southward of this isle, the current is found to ex-

[1] See "*A Thought concerning the Sugar Islands,*" Part II. page 107, of this volume.

tend itself as far north as 41° 20′ or 30′, then it turns towards the E. S. E. or S. E. $\frac{1}{4}$ E.

Having passed the Isle of Sables, shape your course for the St. George's Banks, so as to pass them in about latitude 40°, because the current southward of those banks reaches as far north as 39°. The shoals of those banks lie in 41° 35′.

After having passed St. George's Banks, you must, to clear Nantucket, form your course so as to pass between the latitudes 38° 30′ and 40° 45′.

The most southern part of the shoals of Nantucket lie in about 40° 45′. The northern part of the current, directly to the south of Nantucket, is felt in about latitude 38° 30′.

By observing these directions and keeping between the stream and the shoals, the passage from the banks of Newfoundland to New York, Delaware, or Virginia, may be considerably shortened; for so you will have the advantage of the eddy current, which moves contrary to the Gulph Stream. Whereas if to avoid the shoals you keep too far to the southward, and get into that stream, you will be retarded by it at the rate of 60 or 70 miles a-day.

The Nantucket whale-men being extremely well acquainted with the Gulph Stream, its course, strength, and extent, by their constant practice of whaling on the edges of it, from their island quite down to the Bahamas, this draft of that stream was obtained from one of them, captain Folger,

and caused to be engraved on the old chart in London, for the benefit of navigators, by

B. FRANKLIN.

Note. The Nantucket captains who are acquainted with this stream, make their voyages from England to Boston in as short a time generally as others take in going from Boston to England, viz. from twenty to thirty days.

A stranger may know when he is in the Gulph Stream, by the warmth of the water, which is much greater than that of the water on each side of it. If then he is bound to the westward, he should cross the stream to get out of it as soon as possible.

B. FRANKLIN.

OBSERVATIONS *of the Warmth of the* SEA-WATER, *&c. by Fahrenheit's Thermometer, in crossing the* GULPH STREAM; *with other Remarks made on board the Pennsylvania Packet, Captain Osborne, bound from London to Philadelphia, in April and May*, 1775.

Date.	Hour.	Temp. of Air.	Temp. of Wat.	Wind.	Course.	Distance.	Latitude N.		Longitude W.		Remarks.
April 10			62								
11			61								
12			64								
13			65								
14			65								
26		60	70				37°	39′	60°	38′	Much gulph weed; saw a whale.
27		60	70	S S E	W b S		37	13	62	29	Color of water changed.
28	8 A.M.	70	64	S W	W N W		37	48	64	35	No gulph weed.
—	6 P.M.	67	60			34					Sounded, no bottom.
29	8 A.M.	63	71	N	W	44	37	26	66	0	Much light in the water last night.
—	5 P.M.	65	72	N E	W b S	57					Water again of the usual deep sea color, little or no light in it at night.
—	11 dit.	66	66	N W b N							
30	8 A.M.	64	70	N E	W b N	69					
—	12	62	70		E b S	24	37	20	68	53	Frequent gulph weed; water continues of sea color; little light.
—	6 P.M.	64	72	E S E	W b N	43					
—	10 dit.	65	65	S		25					Much light.
May 1	7 A.M.	68	63			60					Much light all last night.
—	12	65	56	S S W	W N W	44	38	13	72	23	Color of water changed.
—	4 P.M.	64	56		W b N	21					
—	10 dit.	64	57	S W	W N W	31					Much light.
2	8 A.M.	62	53			18	38	43	74	3	Much light. Thunder-gust.
—	12	60	53	W S W	N W	18					
—	6 P.M.	64	55	N W	W S W	15					
—	10	65	[illegible]	N b W	W b N	10					
3	7 A.M.	62	54			30	38	30	75	0	

OBSERVATIONS *of the* WARMTH *of the* SEA-WATER, *&c. by Fahrenheit's Thermometer; with other Remarks, made on board the Reprisal, Capt. Wyck's, bound from Philadelphia to France, in October and November,* 1776.

Date.		Hour A. M.	Hour P. M.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Lat. N.		Long. W.		Remarks.
Oct.	31	10		76	70	S S E	E b S	135	38	12	70	30	Left the capes Thursday night, Oct. 29, 1776.
	—		4		71								
Nov.	1	10			78	W S W	E ½ N	109	No ob.		68	12	
	—		4	71	81								
	2	8		71	75	N							
	—	1			78			141	ditto.		65	23	
	—		4	67	76								Some sparks in the water these two last nights.
	3	8			76	N W	E S E ½ E						
	—	12			76		E b S	160	37	0	62	7	
	—		4	70	76								
	4	9		68	76		N b E						Ditto.
	—		1		76			194	36	26	58	8	
	—		4	68	76								
	—		8		78								
	5	8		68	76		N E						
	—	12		70	75								Ditto.
	—		4		75			163	35	21	55	3	
	—		8		75								
	6	8			76	E b N	S 50 E						
	—	12			77			75	35	33	53	52	
	7	8			78	S E b E	N 30 W						
	—	12			77			108	36	6	52	46	
	—		4		77								
	8	9		75	77	S b E	N 49 E						
	—	12			77			175	38	2	50	1	
	—		4		77								
	9	9		75	77								
	—	12		75	70	S W	N 33 E	175	39	39	46	55	

OBSERVATIONS MADE ON BOARD THE REPRISAL, CONTINUED.

Date.	Hour A.M.	Hour P.M.	Temp. of Air.	Temp. of Water.	Wind.	Course.	Distance.	Lat. N. °	Lat. N. ′	Long. W. °	Long. W. ′	Remarks.
Nov. 9		4		71								
10	8		70	68								
—	12			64	E	N 17 E	64	40	39	46	27	
11	8			63								
—	12			61	S E	N 8 E	41	41	19	46	19	
12	8		56	59								
—		4		69	N N W	N 80 E	120	41	39	43	42	
13	all	day		68	E	S 82 E	69	41	29	42	10	
14	8		70	70		N 74 E	111	42	0	39	57	
—		Noon		72	E S E							
—		4		71								
15	8		61	69								
—		Noon		68	W S W	N 70 E	186	43	3	35	51	
—		4		67								
16		Noon	65	67	S W	N 67 W	48	43	22	34	50	
—		4		63								
17	8			63	E S E	N 19 E	56	44	15	31	25	
18	all	day		65	S b W	N 75 E	210	45	6	29	43	Some gulph weed.
19		Noon	65	64	S W	N 80 E	238	45	46	24	2	
20	8			62	N	S 80 E	155	45	19	20	30	
—		4		60								
21	9			62	S	N 88 E	94	45	22	18	17	
22	10		60	62	S S W	S 89 E	133	45	19	15	19	
23		Noon		61	W S W	S 86 E	194	45	6	10	35	
24		do.		60	N N E	N 78 E	191	45	46	6	10	
25		do.		60	N E	S 76 E	125	45	4	3	23	
26		do.	56	60	E	N 73 E	31	45	13	2	20	
27		do.		58								
28		do.	54	56								Soundings off Bellisle.

A JOURNAL *of a* VOYAGE *from the Channel between France and England towards America.*

Dates.		Latit. N.	Long. W.	Therm. A. M. Air.	Therm. A. M. Water.	Therm. P. M. Air.	Therm. P. M. Water.	Winds.	Course.	Distance.	Variation of the Needle.	Therm. Noon A.	Therm. Noon W.
July	29			62	57			These are taken on an average of 24 hours.					
	30			62	58	63	58						
	31			60	58	62	62			Miles.	West.		
August	1	49 15	4 15	63	62	60	64	East	S W ½ W	60	22° 0′		
	2	48 28	8 58	64	64	64	63	E S E	W b S ½ S	174			
	3	47 0	12 13	60	67	omitted		N E	S W b W	160			
	4	45 0	15 43	66	66	do.	66	N W b W	S W ½ W	190			
	5	43 5	17 25	67	65	65	68	N E	S W b S	131	20 0		
	6	41 3	19 44	70	68	71	69	N E	S W ½ S	166	16 30		
	7	38 45	21 34	70	70	68	70	N E	S S W ¾ W	165	11 30		
	8	36 42	23 10	72	71	73	72	N E	S S W ¾ W	149	11 15		
	9	35 40	25 40	73	73	73	74	N E	W S W ¼ S	137			
	10	35 0	27 0	71	73	77	75	N W	W S W ¾ S	76			
	11	33 51	28 42	74	74	76	77	North	S W ¾ W	112			
	12	33 30	31 30	76	75	76	76	North	W ¾ S	143			
	13	33 17	33 32	76	76	78	77	N E	W ½ S	103		77	78
	14	33 22	34 31	76	76	81	79	S S E	W ½ N	50		81	79
	15	33 45	35 0	78	79	79	78	W N W	S W ¼ W	35		79	79
	16	34 11	35 30	79	78	81	80	West	N W ½ N	38		81	80
	17	35 37	36 4	80	79	80	78	W S W	N N W	75		80	78
	18	36 7	37 16	80	78	omitted		N W b W	W N W ½ N	65		80	79
	19	36 38	38 0	78	77	78	77	W S W	N W ½ W	49		79	77

JOURNAL OF A VOYAGE, &c. CONTINUED.

Dates.		Lat. N.		Long. W.		Therm. A. M.		Therm. P. M.		Winds.	Course.	Distance.	Variation of the Needle.		Therm. Noon	
						Air.	Water.	Air.	Water.						A.	W.
Aug.	20	37	38	38	6	78	76	omitted		West	N ¼ W	62			77	75
	21	36	15	38	32	73	74	78	76	W N W	S b W	82			77	75
	22	35	40	38	44	77	76	80	77	W b S	S S W	38			80	77
	23	35	35	40	52	79	77	78	75	North	W ¼ S	100			omitted	
	24	35	12	41	31	75	73	75	74	W N W	S W b W	41			75	74
	25	35	40	42	33	79	76	79	76	W b N	W N W ¾ N	60			80	76
	26	35	30	42	44	79	76	80	76	S W b W	S W ½ S	14			80	76
	27	35	14	43	23	79	77	81	79	West	W S W ¼ S	38			81	78
	28	34	23	44	0	78	76	78	78	N N E	S W b S	60			78	78
	29	34	12	45	52	77	78	78	78	N E	W ¼ S	94	8	0	79	78
	30	34	5	48	31	78	78	78	78	East	W ½ S	134			78	78
	31	34	20	51	4	80	79	81	79	East	W ¾ S	129			80	80
Sept.	1	34	20	52	47	81	78	omitted		S S W	W ¼ N	36			83	80
	2	34	55	55	12	81	80	83	80	S W	W b N ½ W	125			83	80
	3	35	30	57	24	83	80	83	80	S W b S	W b N ½ N	114	6	0	84	81
	4	35	50	59	1	82	80	83	80	S W ½ W	W b N ¼ N	82			83	81
	5	35	55	61	0	81	80	82	81	S S W	W ¼ N	96			82	81
	6	36	20	62	30	80	81	79	80	N W b N	W b N	75			78	80
	7	34	50	63	10	87	80	78	81	N W b N	S S W	86			78	81
	8	34	45	64	40	75	79	75	79	North	W ¼ S	74			75	79
	9	35	43	66	42	75	79	77	73	N E	W N W	108			78	80
	10	37	20	68	40	77	73	77	70	E N E	N W	126			78	72

N.B. Longitude is reckoned from London, and the Thermometer is according to Fahrenheit.

OBSERVATIONS.

July 31. At one P. M. the Start bore WNW. distant six leagues.

August 1. The water appears luminous in the ship's wake.

— 2. The temperature of the water is taken at eight in the morning and at eight in the evening.

— 6. The water appears less luminous.

— 7. Formegas SW. dist. 32½ deg. St. Mary's SW½S. 33 leagues.

— 8. From this date the temperature of the water is taken at eight in the morning and at six in the evening.

— 10. Moonlight, which prevents the luminous appearance of the water.

— 11. A strong southerly current.

— 12. Ditto. From this date the temperature of the air and water was taken at noon, as well as morning and evening.

— 16. Northerly current.

— 19. First saw gulph weed.

— 21. Southerly current.

— 22. Again saw gulph weed.

— 24. The water appeared luminous in a small degree before the moon rose.

— 29. No moon, yet very light in the water.

— 30. Much gulph-weed to-day.

— 31. Ditto.

Sept. 1. Ditto.

Sept. 2. A little more light in the water.

— 4. No gulph weed to-day. More light in the water.

— 5. Some gulph weed again.

— 6. Little light in the water. A very hard thunder-gust in the night.

— 7. Little gulph weed.

— 8. More light in the water. Little gulph weed.

— 9. Little gulph weed. Little light in the water last evening.

— 10. Saw some beds of rock-weed; and we were surprised to observe the water six degrees colder by the thermometer than the preceding noon.

This day (10th) the thermometer still kept descending, and at five in the morning of the 11th, it was in water as low as 70, when we struck soundings. The same evening the pilot came on board, and we found our ship about five degrees of longitude a-head of the reckoning, which our captain accounted for by supposing our course to have been near the edge of the gulph stream, and thus an eddy-current always in our favor. By the distance we ran from Sept. 9, in the evening, till we struck soundings, we must have then been at the western edge of the gulph stream, and the change in the temperature of the water was probably owing to our suddenly passing from that current into the waters of our climate.

On the 14th of August the following experiment was made. The weather being perfectly calm, an empty bottle, corked very tight, was sent down 20 fathoms, and it was drawn up still empty. It was then sent down again 35 fathoms, when, the weight of the water having forced in the cork, it was drawn up full; the water it contained was immediately tried by the thermometer, and found to be 70, which was six degrees colder than at the surface: the lead and bottle were visible, but not very distinctly so, at the depth of 12 fathoms; but when only 7 fathoms deep, they were perfectly seen from the ship. This experiment was thus repeated Sept. 11, when we were in soundings of 18 fathoms. A keg was previously prepared with a valve at each end, one opening inward, the other outward; this was sent to the bottom, in expectation that by the valves being both open when going down, and both shut when coming up, it would keep within it the water received at bottom. The upper valve performed its office well, but the under one did not shut quite close, so that much of the water was lost in hauling it up the ship's side. As the water in the keg's passage upwards could not enter at the top, it was concluded that what water remained in it was of that near the ground; and on trying this by the thermometer, it was found to be at 58, which was 12 degrees colder than at the surface.

This last journal was obligingly kept for me by

Mr. J. Williams, my fellow-passenger in the London Packet, who made all the experiments with great exactness.

The chart here given has been constructed with a view to give a more comprehensive idea of the course of the Gulph Stream. Volney very plausibly suggests, that the earth deposited by the Gulph Stream S. E. of Newfoundland, has formed the great banks; and that the accumulation there has given the stream a new or more eastwardly direction. This chart also serves to illustrate the long received ideas of the progress of the shoals of fish. May not the glutinous matter seen on the water, and which all persons who have been across the line must have noticed, be another cause of the phenomena of fish-shoals? May they not come in search of the food, which the matter seen on the water in such abundance affords? The writer of this note has observed, that on entering the trade-winds, the seamen have judged of the change of wind approaching by the direction of the bonetta and other fish, which pass in shoals in the South Atlantic and South-eastern Seas, in a direction opposite to the wind; and when not opposite to the prevailing wind, they conclude a change to be at hand from the direction towards which the fish go. The appearance of luminous floating matter

at night is often followed by shoals of fish; the spawn or gluten which the writer has had taken up in a bucket, has been often found as large as two inches diameter, and frequently induced an opinion that it was a species of maritime *cocoon* or egg of an animal; fragments of irregular shaped gluten have been also often seen. An inquiry into the periodical appearance of these luminous substances, on voyages to the southward, and remarks on the usual direction of the shoals of bonetta and other fish, might perhaps lead to very interesting discoveries; it might be assumed as a question worthy of examination, whether the direction of shoals of fish is not towards those points from which periodical winds or currents move the waters; and if the shoals of fish which move from the north poles, and by the British isles across the Atlantic, are not led by their instincts in search of these periodical supplies of food; and if the deposits made by the Gulph Stream on the banks of Newfoundland is not the true cause of the great abundance of fish found there. (*Note by an American Gentleman.*)

ON THE PERNICIOUS QUALITY OF LEAD.—COLICA PICTORUM FROM RAIN-WATER, &c.

To B. Vaughan, Esq.

Dear Friend, *Philadelphia, July* 31, 1786.

I recollect that when I had the great pleasure of seeing you at Southampton, now a twelvemonth since, we had some conversation on the bad effects of lead taken inwardly, and that at your request I promised to send you in writing, a particular account of several facts I then mentioned to you, of which you thought some good use might be made. I now sit down to fulfil that promise.

The first thing I remember of this kind, was a general discourse in Boston, when I was a boy, of a complaint from North Carolina against New England rum, that it poisoned their people, giving them the dry belly-ache, with a loss of the use of their limbs. The distilleries being examined on the occasion, it was found that several of them used leaden still heads and worms, and the physicians were of opinion that the mischief was occasioned by that use of lead. The legislature of the Massachusetts thereupon passed an act, prohibiting under severe penalties the use of such still heads and worms thereafter. Enclosed I send you a copy of the act, taken from my printed law book.

In 1724, being in London, I went to work in the printing-house of Mr. Palmer, Bartholomew Close, as a compositor. I there found a practice I had never seen before, of drying cases of types (which are wet in distribution) by placing it sloping before the fire. I found this had the additional advantage, when the types were not only dried but heated, of being comfortable to the hands working over them in cold weather. I therefore sometimes heated my case when the types did not want drying. But an old workman observing it, advised me not to do so, telling me, I might lose the use of my hands by it, as two of our companions had nearly done; one of whom, that used to earn his guinea a week, could not then make more than ten shillings; and the other, who had the dangles, but seven and sixpence. This, with a kind of obscure pain that I had sometimes felt, as it were in the bones of my hand, when working over the types made very hot, induced me to omit the practice. But talking afterwards with Mr. James, a letter-founder in the same close, and asking him if his people, who worked over the little furnaces of melted metal, were not subject to that disorder; he made light of any danger from the effluvia, but ascribed it to particles of the metal swallowed with their food by slovenly workmen, who went to their meals after handling the metal, without well washing their fingers, so that some of the metalline particles were taken off by their bread and eaten

with it. This appeared to have some reason in it. But the pain I had experienced, made me still afraid of those effluvia.

Being in Derbyshire at some of the furnaces for smelting of lead ore, I was told that the smoke of those furnaces was pernicious to the neighboring grass and other vegetables. But I do not recollect to have heard any thing of the effect of such vegetables eaten by animals. It may be well to make the inquiry.

In America, I have often observed that on the roofs of our shingled houses, where moss is apt to grow in northern exposures, if there be any thing on the roof painted with white lead, such as balusters, or frames of dormant windows, &c. there is constantly a streak on the shingles from such paint down to the eaves, on which no moss will grow, but the wood remains constantly free from it. We seldom drink rain-water that falls on our houses; and if we did, perhaps the small quantity of lead descending from such paint, might not be sufficient to produce any sensible ill effect on our bodies. But I have been told of a case in Europe, I forget the place, where a whole family was afflicted with what we call the dry belly-ache, or *colica pictorum*, by drinking rain-water. It was at a country seat, which, being situated too high to have the advantage of a well, was supplied with water from a tank, which received the water from the leaded roofs. This had been drank several years without

mischief; but some young trees planted near the house, growing up above the roof, and shedding their leaves upon it, it was supposed an acid in those leaves had corroded the lead they covered, and furnished the water of that year with its baneful particles and qualities.

When I was in Paris with Sir John Pringle in 1767, he visited *La Charité*, a hospital particularly famous for the cure of that malady, and brought from thence a pamphlet containing a list of the names of persons, specifying their professions or trades, who had been cured there. I had the curiosity to examine that list, and found that all the patients were of trades that, some way or other, use or work in lead; such as plumbers, glaziers, painters, &c. excepting only two kinds, stone-cutters, and soldiers. These I could not reconcile to my notion, that lead was the cause of that disorder. But on my mentioning this difficulty to a physician of that hospital, he informed me that the stone-cutters are continually using melted lead to fix the ends of iron ballustrades in stone; and that the soldiers had been employed by painters, as laborers, in grinding of colors.

This, my dear friend, is all I can at present recollect on the subject. You will see by it, that the opinion of this mischievous effect from lead, is at least above sixty years old; and you will observe with concern, how long an useful truth may

be known, and exist, before it is generally received and practised on.

I am ever, yours most affectionately,

B. Franklin.

ON THERMOMETERS.

Sept. 13, 1786.

The two thermometers most generally in use at present among the philosophers of Europe, are those of Reaumur and Fahrenheit. The French use Reaumur's, the English Fahrenheit's.

In their respective graduations, Reaumur marked his freezing point 0, Fahrenheit fixed his at 32 of his degrees above 0, and two of his degrees are just equal to one of Reaumur's. I know that in some instruments this equality is not exact; but in two which I have, the one Reaumur's, made by Cappy in Paris, the other Fahrenheit's, by Nairne, London; it is precisely so, they hanging together in the same room. And those workmen are famed for their exactness.

In reading, one frequently finds degrees of heat and cold mentioned, as measured by one or the other of those thermometers, and one is at a loss to reduce that least known to the other.

RULE.

Suppose the degree mentioned is 25 of Reaumur, which is 25 degrees above 0, or his freezing point, and you would know to what degree of Fahrenheit that answers;

Double the 25, which will give you 50 of Fahrenheit's, and to them add 32, his number at the freezing point, and you will have 82, the degree of Fahrenheit's equal to 25 of Reaumur.

On the contrary, if you would reduce Fahrenheit to Reaumur, first subtract 32, and then take half of the remainder; thus taking 32 from 82, there remains 50, and the half of 50 is 25.

This answers in all cases where the degree is above the freezing point.

If below, double the degrees of Reaumur; and subtract them from the 32 of Fahrenheit, which will give you the equivalent degree of his scale. Thus suppose it 5 below 0, or the freezing point of Reaumur; twice 5 is 10, which deducted from 32, Fahrenheit's freezing point, gives you 22 as the equivalent degree of his thermometer.

And halving the degrees of Fahrenheit that are less than 32, you have the degree of Reaumur. Thus 22 of Fahrenheit being 10 degrees less than 32, the half of 10 is 5, the equivalent degree of Reaumur.

B. FRANKLIN.

ON BALLOONS—PIGEONS KILLED BY LIGHTNING.

To M. LE ROY.

Philadelphia, April 18, 1787.

MY DEAR OLD FRIEND,

I believe I have not written to you since I received your kind letters of July 26, and October 9, 1786. Such has been my continual occupation in public and private business, having the building of three houses upon my hands, that I had no time left for philosophical correspondence. I now take up my pen with the honest resolution of paying off some of my debts.

You mention that M. De Buffon *avoit des douleurs semblables aux miennes*. I sympathise with him. Let me know in your next how he does. I do not understand these dispensations of Providence, though probably they are for the best. But it seems to me, that if you or I had the disposition of good and evil in this world, so excellent a man would not have an hour's pain during his existence.

Your account of the progress made in the art of ballooning, by the acquisition of a tight *enveloppe*, and the means of descending and rising without throwing out ballast, or letting out air, is very pleasing. I am sorry the artists at *Javelle* do not continue their experiments. I always thought they were in the likeliest way of making improvements, as they were remote from interruption in their ex-

periments. I have sometimes wished I had brought with me from France, a balloon sufficiently large to raise me from the ground. In my malady it would have been the most easy carriage for me, being led by a string held by a man walking on the ground. I should be glad to have Mr. Meunier's work. Pray let Mr. Grand know where he may buy it for me.

It gives me pleasure to hear of the success attending the conductors at Brest and at Dijon. Time will bring them more into use, and of course make them more useful.

It is a curious fact, that of the death of so many pigeons by lightning without disturbing their position. Pray when you see M. De Malesherbes, present to him my respects. He is one of the most respectable characters of this age.

Believe me ever, my dear friend, with the sincerest esteem and respect, yours most affectionately,

B. FRANKLIN.

ON THE UTILITY OF LIGHTNING CONDUCTORS.

TO M. LANDRIANI.

SIR, *Philadelphia, Oct.* 14, 1787.

I received by the hand of Mr. Gibbs your excellent dissertation, *dell' utilita dei conduttori elettrici,* which you have had the goodness to send me. I have read it with great pleasure. Be pleased to accept my hearty thanks.

I find upon my return to this country, that the number of conductors is greatly increased; their utility having been made manifest by many instances of their good effect in preserving buildings. Among others, my own house in my absence received a great stroke, which was visible to the neighbors, who immediately ran in to see if any damage was done, or any fire commenced, which might by their assistance be extinguished. They found nothing disordered, and the family only much frightened by the loudness of the explosion. On making an addition to my house last year, the conductor was taken down to be removed, when I found that the copper point which had been nine inches long, and in its thickest part about one-third of an inch in diameter, had been almost all melted and blown away, very little of it remaining attached to the iron rod. So that at length the invention has been of some use to the inventor, and afforded an additional pleasure to that of having seen it useful to others. Mr. Rittenhause, our astronomer, informs me, that having inspected with his excellent telescope many conductors that are within his view, he finds that the points of a number of them have also been melted; and we have no instance of any considerable damage done to any houses that were furnished with a complete conductor, and very few of damage to any other houses in this city since conductors became common.

With great esteem and respect, I have the honor to be, sir, your most obedient and most humble servant,

B. FRANKLIN.

ON THE EARTH'S MAGNETISM, &c.

TO THE HON. J. BOWDOIN, ESQ.

DEAR SIR, *Philadelphia, May* 31, 1788.

* * * * * *

OUR ancient correspondence used to have something philosophical in it. As you are now more free from public cares, and I expect to be so in a few months, why may we not resume that kind of correspondence? Our much regretted friend Winthrop once made me the compliment, that I was good at starting game for philosophers. Let me try if I can start a little for you.

Has the question, How came the earth by its magnetism, ever been considered?

Is it likely that *iron ore* immediately existed when this globe was first formed, or may it not rather be supposed a gradual production of time?

If the earth is at present magnetical in virtue of the masses of iron ore contained in it, might not some ages pass before it had magnetic polarity?

Since iron ore may exist without the polarity, and by being placed in certain circumstances, may obtain it from an external cause; is it not possible that the earth received its magnetism from some such cause?

In short, may not a magnetic power exist throughout our system, perhaps through all systems, so that if men could make a voyage in the starry regions, a compass might be of use? And may not such universal magnetism with its uniform direction, be serviceable in keeping the diurnal revolution of a planet more steady to the same axis?

Lastly, as the poles of magnets may be changed by the presence of stronger magnets, might not in ancient times the near passing of some large comet of greater magnetic power than this globe of ours, have been a means of changing its poles, and thereby wracking and deranging its surface, placing in different regions the effect of centrifugal force, so as to raise the waters of the sea in some, while they were depressed in others?

Let me add another question or two, not relating indeed to magnetism, but however, to the theory of the earth.

Is not the finding of great quantities of shells and bones of animals (natural to hot climates) in the cold ones of our present world, some proof that its poles have been changed?

Is not the supposition that the poles have been changed, the easiest way of accounting for the deluge, by getting rid of the old difficulty how to dispose of its waters after it was over? since if the poles were again to be changed, and placed in the present equator, the sea would fall there about 15

miles in height, and rise as much in the present polar regions: and the effect would be proportionable if the new poles were placed anywhere between the present and the equator.

Does not the apparent wrack of the surface of this globe, thrown up into long ridges of mountains with strata in various positions, make it probable, that its internal mass is a fluid, but a fluid so dense as to float the heaviest of our substances? Do we know the limit of condensation air is capable of? Supposing it to grow denser *within* the surface, in the same proportion nearly as we find it does *without*, at what depth may it be equal in density with gold?

Can we easily conceive how the strata of the earth could have been so deranged, if it had not been a mere shell supported by a heavier fluid? Would not such a supposed internal fluid globe be immediately sensible of a change in the situation of the earth's axis, alter its form, and thereby burst the shell, and throw up parts of it above the rest; as if we could alter the position of the fluid contained in the shell of an egg, and place its longest diameter where the shortest now is, the shell must break; but would be much harder to break if the whole internal substance were as solid and hard as the shell?

Might not a wave by any means raised in this supposed internal ocean of extremely dense fluid, raise in some degree as it passes the present shell

of incumbent earth, and break it in some places, as in earthquakes? And may not the progress of such wave, and the disorders it occasions among the solids of the shell, account for the rumbling sound being first heard at a distance, augmenting as it approaches, and gradually dying away as it proceeds? a circumstance observed by the inhabitants of South America in their last great earthquake, that noise coming from a place some degrees north of Lima, and being traced by inquiry quite down to Buenos Ayres, proceeding regularly from north to south, at the rate of leagues per minute, as I was informed by a very ingenious Peruvian whom I met with at Paris.

I am ever, my very dear friend, yours most affectionately, B. FRANKLIN.

DESCRIPTION OF THE PROCESS TO BE OBSERVED IN MAKING LARGE SHEETS OF PAPER IN THE CHINESE MANNER, WITH ONE SMOOTH SURFACE.[1]

IN Europe to have a large surface of paper connected together and smooth on one side, the following operations are performed.

1. A number of small sheets are to be made separately.

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[1] Communicated by Dr. Franklin to the American Philosophical Society, in which it was read, June 20, 1788.

2. These are to be couched, one by one, between blankets.

3. When a heap is formed it must be put under a strong press, to force out the water.

4. Then the blankets are to be taken away, one by one, and the sheets hung up to dry.

5. When dry they are to be again pressed, or if to be sized, they must be dipped into size made of warm water, in which glue and alum are dissolved.

6. They must then be pressed again to force out the superfluous size.

7. They must then be hung up a second time to dry, which, if the air happens to be damp, requires some days.

8. They must then be taken down, laid together, and again pressed.

9. They must be pasted together at their edges.

10. The whole must be glazed by labor, with a flint.

In China, if they would make sheets, suppose of four and a half ells long and one and a half ells wide, they have two large vats, each five ells long and two ells wide, made of brick, lined with a plaster that holds water. In these the stuff is mixed ready to work.

Between these vats is built a kiln or stove, with two inclining sides: each side something larger than the sheet of paper; they are covered with a fine stucco that takes a polish, and are so con-

trived as to be well heated by a small fire circulating in the walls.

The mould is made with thin but deep sides, that it may be both light and stiff: it is suspended at each end with cords that pass over pullies fastened to the ceiling, their ends connected with a counterpoise nearly equal the weight of the mould.

Two men, one at each end of the mould, lifting it out of the water by the help of the counterpoise, turn it and apply it with the stuff to the smooth surface of the stove, against which they press it, to force out great part of the water through the wires. The heat of the wall soon evaporates the rest, and a boy takes off the dried sheet by rolling it up. The side next the stove receives the even polish of the stucco, and is thereby better fitted to receive the impression of fine prints. If a degree of sizing is required, a decoction of rice is mixed with the stuff in the vat.

Thus the great sheet is obtained, smooth and sized, and a number of the European operations saved.

As the stove has two polished sides, and there are two vats, the same operation is at the same time performed by two other men at the other vat; and one fire serves.

NEW AND CURIOUS THEORY OF LIGHT AND HEAT.

ADDRESSED TO DAVID RITTENHAUSE, ESQ.

Nov. 20, 1788.

UNIVERSAL space, as far as we know of it, seems to be filled with a subtle fluid, whose motion, or vibration, is called light.

This fluid may possibly be the same with that which, being attracted by, and entering into other more solid matter, dilates the substance by separating the constituent particles, and so rendering some solids fluid, and maintaining the fluidity of others; of which fluid, when our bodies are totally deprived, they are said to be frozen; when they have a proper quantity, they are in health, and fit to perform all their functions; it is then called natural heat: when too much, it is called fever; and when forced into the body in too great a quantity from without, it gives pain, by separating and destroying the flesh, and is then called burning, and the fluid so entering and acting is called fire.

While organised bodies, animal or vegetable, are augmenting in growth, or are supplying their continual waste, is not this done by attracting and consolidating this fluid called fire, so as to form of it a part of their substance? And is it not a separation of the parts of such substance which, dis-

solving its solid state, sets that subtle fluid at liberty, when it again makes its appearance as fire?

For the power of man relative to matter, seems limited to the separating or mixing the various kinds of it, or changing its form and appearance by different compositions of it; but does not extend to the making or creating new matter, or annihilating the old. Thus, if fire be an original element or kind of matter, its quantity is fixed and permanent in the universe. We cannot destroy any part of it, or make addition to it; we can only separate it from that which confines it, and so set it at liberty: as when we put wood in a situation to be burnt, or transfer it from one solid to another, as when we make lime by burning stone, a part of the fire dislodged in the fuel being left in the stone. May not this fluid, when at liberty, be capable of penetrating and entering into all bodies, organised or not, quitting easily in totality those not organised, and quitting easily in part those which are; the part assumed and fixed remaining till the body is dissolved?

Is it not this fluid which keeps asunder the particles of air, permitting them to approach, or separating them more, in proportion as its quantity is diminished or augmented?

Is it not the greater gravity of the particles of air, which forces the particles of this fluid to mount

with the matters to which it is attached, as smoke or vapor?

Does it not seem to have a greater affinity with water, since it will quit a solid to unite with that fluid, and go off with it in vapor, leaving the solid cold to the touch, and the degree measurable by the thermometer?

The vapor rises attached to this fluid, but at a certain height they separate, and the vapor descends in rain, retaining but little of it, in snow or hail less. What becomes of that fluid? Does it rise above our atmosphere, and mix with the universal mass of the same kind?

Or does a spherical stratum of it, denser, as less mixed with air, attracted by this globe, and repelled or pushed up only to a certain height from its surface, by the greater weight of air, remain there surrounding the globe, and proceeding with it round the sun?

In such case, as there may be a continuity or communication of this fluid through the air quite down to the earth, is it not by the vibrations given to it by the sun, that light appears to us? And may it not be, that every one of the infinitely small vibrations, striking common matter with a certain force, enters its substance, is held there by attraction, and augmented by succeeding vibrations, till the matter has received as much as their force can drive into it?

Is it not thus, that the surface of this globe is continually heated by such repeated vibrations in the day, and cooled by the escape of the heat when those vibrations are discontinued in the night, or intercepted and reflected by clouds?

Is it not thus, that fire is amassed and makes the greatest part of the substance of combustible bodies?

Perhaps, when this globe was first formed, and its original particles took their place at certain distances from the centre, in proportion to their greater or less gravity, the fluid fire, attracted towards that centre, might in great part be obliged, as lightest, to take place above the rest, and thus form the sphere of fire above supposed, which would afterwards be continually diminishing by the substance it afforded to organised bodies, and the quantity restored to it again, by the burning or other separating of the parts of those bodies.

Is not the natural heat of animals thus produced, by separating in digestion the parts of food, and setting their fire at liberty?

Is it not this sphere of fire which kindles the wandering globes that sometimes pass through it in our course round the sun, have their surface kindled by it, and burst when their included air is greatly rarefied by the heat on their burning surfaces?

May it not have been from such considerations, that the ancient philosophers supposed a sphere of fire to exist above the air of our atmosphere?

B. FRANKLIN.

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